

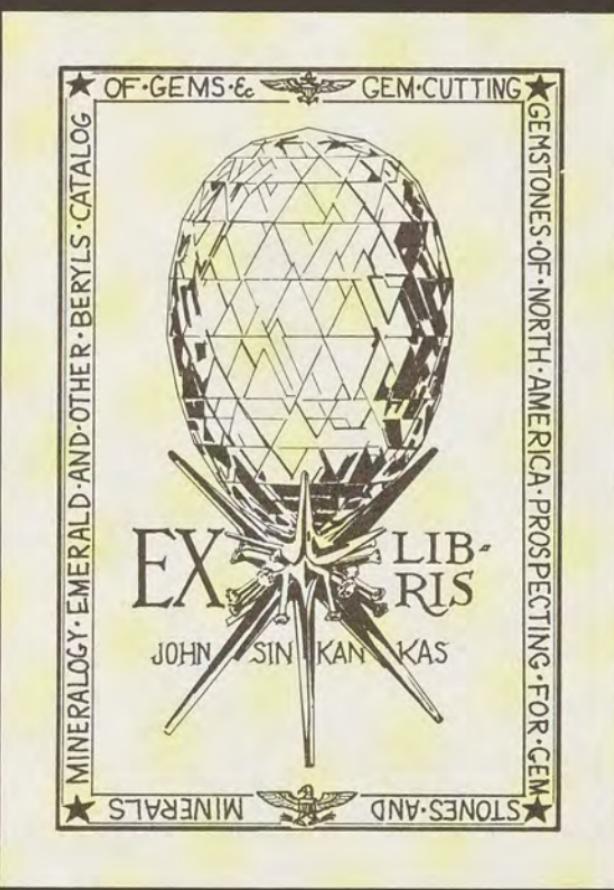
THE  
PROSPECTOR'S  
HANDBOOK  
—  
ANDERSON

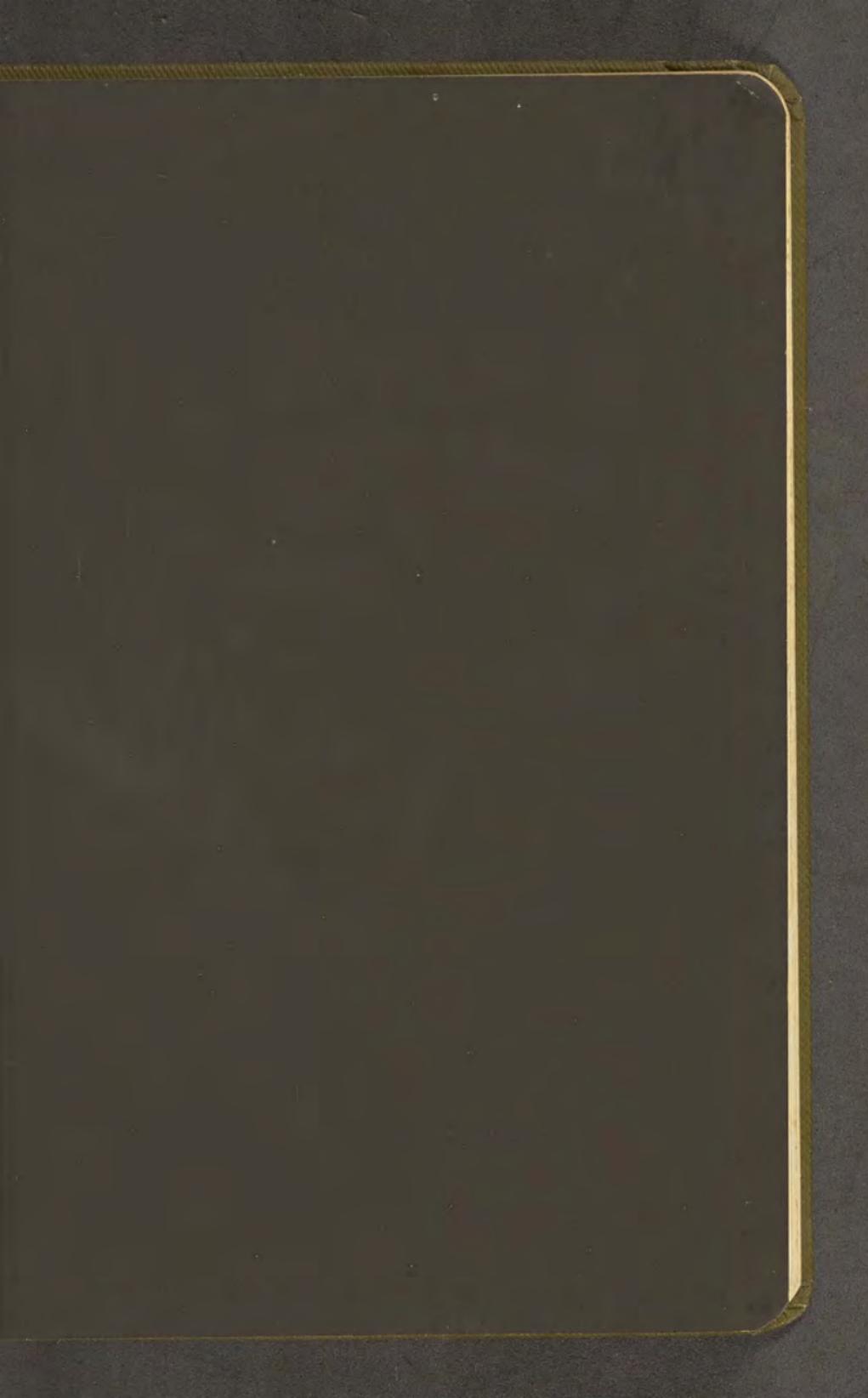


CONDITIONS UNDER WHICH GOLD IS USUALLY FOUND



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THE  
PROSPECTOR'S HANDBOOK

*A GUIDE FOR THE PROSPECTOR AND  
TRAVELLER IN SEARCH OF METAL-BEARING  
OR OTHER VALUABLE MINERALS*

BY

J. W. ANDERSON, M.A. (Cantab.), F.R.G.S.

AUTHOR OF "FIJI AND NEW CALEDONIA"

Tenth Edition



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## PREFACE.

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To the lover of natural history, no matter in whatever part of the world he may travel, each tract of country offers object after object, subject after subject, of interest. He reads sermons in stones and rocks wherever fate happens to direct his footsteps ; and, if he wanders over the bypaths of untrodden ground, derives a pleasure and satisfaction from the wonderful works of nature, such as no one who has not been privileged to experience it can realise.

Geological formations, strange to the eye accustomed, perhaps, to some particular locality, continually attract his attention ; while each river-bed, each mountain-side, and each precipice merits an inspection, if not a close examination.

Accompanied by very many hardships and dangers though the life of a prospector must necessarily be, it doubtless possesses an intrinsic fascination ; certainly there must be some extraordinary charm about his free-and-easy manner of living ; he constantly, during his arduous and hazardous explorations, is buoyed up with the pleasing hope of, some day in the future, he knows not how soon or how late, being fortunate enough to reap a reward for his plodding labour, or, using his own phraseology, to "strike something rich."

After traversing the mineral fields of New Zealand, New Caledonia, New Mexico, and Colorado, I feel fully convinced that some simple guide or handbook for the use of

prospectors as well as travellers is a desideratum. The ordinary miner or prospector discards a lengthy descriptive work on Mineralogy, containing an account of all the known minerals, the majority of which are perfectly useless to him in his struggle for existence ; and again, elaborate means of dealing with his specimens appear only like a puzzle. It is for this reason that I have endeavoured to treat the subject in as brief, though as comprehensive, a manner as possible ; and I hope that these pages will satisfy the requirements of at least some of those toilers who explore the trodden or untrodden tracks on the face of the globe.

I cannot conclude these prefatory remarks without acknowledging with gratitude my indebtedness to many valuable works to which, by the kind permission of the author or the publisher, I have had access. Among these I would especially mention Mr. Robert Hunt's great work, "British Mining;" Mr. D. C. Davies's two comprehensive treatises, entitled respectively "Metalliferous Minerals and Mining" and "Earthy Minerals;" and Lieut.-Col. Ross's recently published work, "The Blowpipe in Chemistry, Mineralogy and Geology." I have also had the privilege of borrowing certain illustrations from these and other works, which I feel sure have greatly added to the value and usefulness of my pages.

*October, 1855.*

## PREFACE TO SEVENTH EDITION.

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SINCE the first edition was published, in the autumn of 1885, several important discoveries and openings up of metal-producing districts in various parts of the world have occurred, and references to these have now been added. Of such, the gold fields of South Africa and Western Australia are the most important; and the circumstances under which the precious metal has been found in the conglomerates of the former have astonished many experts. They certainly suggest an important lesson to the prospector, viz.—That it behoves him to explore a country with a mind open to new impressions. If he does not do so, for instance, in a large tract of land like West Australia, where mineral wealth seems to have been bountifully distributed in so many districts, he will be apt to overlook much that might be valuable.

Opportunity has been taken to refer to Aluminium ores. The metal has undoubtedly a great future before it; the discovery of a bed rich in aluminium ore is not by any means to be despised.

With regard to the Tables for the determination of a mineral by noting the colour and lustre, and then the streak, it should be borne in mind that, purposely, only a limited number of minerals have been tabulated, and also that the matter relating to the extraction of metal from ores and the concentration of minerals is necessarily in a very condensed form.

Since the sixth edition was published (1895), I have returned from a hurried visit to South and East Africa, and I think it worth while to mention here one point that not only applies to South Africa, but also to many other countries. It is that in localities where there is much flat or slightly undulating land, as in the extensive Karoo, the greater part of the country is really most imperfectly prospected, simply because soil, drift, &c., conceal the bed-rock. In Barberton district, which is hilly or mountainous, geological formations are exposed, but this is not the case in most parts of South Africa. That there may perchance be many more auriferous "banket" reefs or quartzites connected with, or distinct from, those already known to exist, no one can dispute, and it is not unreasonable to believe that in the future more diamond-producing mines in Orange Free State or elsewhere may be discovered. It is true that a slight elevation above a diamondiferous "pipe" formation may, in some instances, have been noticeable; at the same time I have heard that in other instances the converse has been the case, or the elevation was not apparent.

In British Guiana, too, much flat land or forest land covered with soil, containing the accumulation of vegetable matter, has retarded discoveries. Of course an outcrop, here and there, of hard rock such as quartz or quartzite may be met with; however, not by any means always. Therefore, especial attention should be taken to explore the banks and beds of rivers and dry creeks, as not unfrequently detached pieces of quartz, &c., and sometimes the lode or deposit formation itself, may be noticed in the river or creek bed.

There is another point which—although it is mentioned elsewhere in this book—cannot be borne in mind too carefully, and that is, that the searcher after minerals should not expect to find free gold or indications of a mineral staring him in the face; he should rather assume that these

may exist, and, in consequence, have samples of rock properly assayed. It is unreasonable to expect an ounce reef to show much free gold even on the outcrop, or by panning out, especially if the gold is in a very finely-divided state. Many years ago, I visited a very extensive gold mine in New Zealand, and never saw a trace of gold in the immense heaps of ore ready for crushing. In this mine the gold was found in the free state and not much mixed with sulphides. So, too, in one of the large mines of Johannesburg—a fifteen-pennyweights-to-the-ton mine—the output from which is more than 10,000 tons per month, the same thing occurred, the gold being concealed, in a very fine state, in the iron pyrites crystals.

In connection with precious stones, mention has been made of a small instrument which, so long as a certain amount of experimenting has been previously made with specimens, might be of much utility to prospectors who usually know but very little about gem stones, and yet who are very likely to meet with them in alluvial washings.

Finally, I take the opportunity of reminding the prospector who has to deal with surface rocks of a point of great importance. Rocks and minerals have to be written about, more or less, as if they were cabinet specimens, although (as every one will understand) many of them have been weathered for thousands of years. Even a description of the appearance of an unweathered rock does not fix itself in a student's mind so well as does the handling or the examination of a specimen. For this reason, I should advise any one who intends setting out on an exploration to make himself as familiar as he can beforehand with the appearance of the most important rocks—such as granite, diorite, schists, silurian rocks, &c.,—and to examine as many gossans as he can, as well as all kinds of oxides, not forgetting tinstone, in various colours; carbonates, chlorides, &c., of the various metals. After which he should learn

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all about the sulphides of metals, tellurides, &c., which may be met with deeper in lodes or deposits. But he must especially remember, that while he is to be busy with surface matter, the mere study of rare and beautiful cabinet specimens, with their perfect crystals, will be of comparatively little use to him.

*February, 1897.*

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## ERRATUM.

In several places throughout the work, for "microsmic" read "microscopic."

ANDERSON's "PROSPECTOR'S HANDBOOK."  
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IN prospecting a country for mineral wealth, it is most important to search very systematically and carefully among the sands and rocks of river beds, in dry creeks, and at the bottom of valleys, as well as on the sea-shore. Not only does the action of running water and glaciers grind down masses and particles, and, through the never-changing law of gravity, deposit the débris on the lower ground: but also, as on the shores of California, Oregon, New Zealand, and elsewhere, the tides of the ocean distribute the disintegrated heavy metals in a regular fashion. The prospector should observe the characteristics of loose rocks found in ravines or gulches, more especially in eddies or dry waterholes where heavy matter is left during freshets, such as are of frequent occurrence in mountainous districts; for the holes and channels and fissures in the solid rock over which a stream runs, or has run, are frequently well worth examining. All earthy deposits being the result of either chemical or mechanical action, they usually serve as a guide to the nature of the constituent parts of the earth's crust in the immediate neighbourhood.

Prospecting for heavy metals left in the form of a deposit is based on one and the same rules, and, consequently, the

search for the precious metal gold may be selected as an exemplification of the method. In searching the sands washed down by rivers, it is well to bear in mind that if the bed of a river flowing through an open country yields fine gold dust, it will probably yield larger dust or grains nearer the mountains from which the stream runs, and grains of gold far along the stream may suggest nuggets nearer the source; because the water which has washed the gold-bearing matter from the lodes in the mountains has washed it, so to speak, down an inclined plane, leaving in its course the heavy particles and transporting the lighter farther away. The richest deposits are often those where the current has been broken by a change of descent or direction, and where a turning is abrupt, so that on one side of the stream is a cliff and on the other a gentle slope; the latter may be very rich in heavy metals. Sometimes there are several of these bends with slopes opposite cliffs, and in these slopes there is more chance of discovering gold than in places where the course of the stream is a straight one. The termination of a mountain chain, too, offers a likely site for alluvial diggings. Very commonly in a canon or gulch, where gold grains are found deposited in the lowest parts along which the river or creek runs, an accumulation of boulders or gravel may be noticed higher up the sides of the range, and more or less parallel to the bed of the creek. Portions of such deposits should be carefully examined by the eye (and by the magnifying glass), and by washing in a basin at the nearest water (as hereafter explained—GOLD, Chapter V.), as the gold-bearing matter, whether carried there in a past age by running water or glacier, may contain rich gold layers close to the "bed-rock" on which the debris rests. Should there be several distinct deposits, the deepest layer of each period is generally the most lucrative. When alluvial ground is made up of rather loose gravel mixed with boulders or lumps of rock, the gold along with other heavy substances will be found underneath the bulk of the coarse deposits, and either remains near to or on the "bed-rock," or mixed with clay; so that the earthy matter just over the "bed-rock" ought to claim much more attention than that elsewhere.

If the clay is likely to contain the precious metal, it ought to be washed very carefully. In prospecting a stream, should the flow of water hinder digging operations, the course of the stream must be diverted by means of back trenches, cut so that the water may flow through them ; in this manner the bed may be laid bare, and then the large rocks or boulders can be easily removed and the finer gravel thoroughly washed by running water. It is advisable to remember that when gold in alluvial ground occurs, the chances are that auriferous lodes—not necessarily payable to work, yet, perhaps, of a far more permanent source of wealth than the gravels will prove—traverse the neighbouring elevations of land, and consequently the country round about should be searched for veins.

In the search for mineral veins or deposits other than alluvial, it is not advisable for a prospector to trouble himself about the comparatively recent formations nor modern volcanic rocks ; for, although certain deposits do occur in the former, and rich auriferous deposits have been worked in Australia and California under formations capped by the latter, it is well to bear in mind that, excepting certain deposits of iron, copper, zinc, lead, &c., and, of course, surface diggings, the metal-bearing minerals are chiefly mined for in the rocks of an older date than those of the Coal measures, though some, as in California, Transylvania, and Hungary, belong to a more recent period. It must also be remembered that a granite, diorite, andesite, or metamorphic rock (schist, quartzite, &c.) country is always worth prospecting.

Without entering into a discussion concerning the formation and origin of veins, about which so much speculation has been rife and so many theories propounded, it suffices to say that certain laws applying to veins in one district apply also, more or less, to those in another. For instance, in any particular district the mineral-bearing lodes generally follow the same direction, that is to say their planes have the same compass-bearing, and consequently are parallel, notwithstanding a considerable distance may separate one lode from the next nearest to it. In some mining districts, a second series of veins runs right across the first and principal ; these lodes, however, are either of a different nature of mineral to that of the first, or if of the same,

poorer in quality. It is well to recollect that a true mineral vein, where it exists, is not likely to be isolated ; it rather represents, in a poorer or richer degree, many more within reach, and which constitute a "mineral belt." For this reason, the explorer should not set his affections too much on any one "claim" until he has to his own satisfaction, if means and time allow, considered the whole district with its numerous lodes as a mineral-bearing one.

In the search for mineral veins, the prospector should study the general geological features of the country, the sections of road cuttings, landslips, precipitous cliffs, the sides of valleys, the sections of banks exposed to view (by the action of water or other denuding agency), river-beds, dry channels and gorges. If he find "likely" stones in a creek or valley, he should travel up it until he notices that similarly constituted stones cease to be seen, and then start up the hill-side to discover the parent rock from which they became detached. Very frequently, while at the base of a hill or mountain, there is a deposit in the form of soil washed down from the more elevated ground, higher up there is "drift" in the form of boulders and detritus, intervening between the surface and the original bed-rock, and thus obscuring the solid rock formation from view.

However, by taking note of the various undulations and avoiding such places where common sense suggests that "drift" would naturally accumulate, the prospector may come across "outcrops," especially in the steep sides of gulleys and backbones of ridges; and, failing this, he may, by travelling towards the summit of any range of hills, be sure, as he approaches the top, to find less "drift" to thwart his investigations. At the same time, though he ought not to be too eager to commence work with his prospecting pick in "drift" of great thickness—say ten or twenty feet—he must, for all that, carefully notice the various "float" stones on the surface of the hill-sides, as by doing so he can often trace the rim of a particular lode hidden from view, and, if no "outcrop" of the same kind of rock has attracted his attention by leaving traces in the form of detached pieces scattered about the slopes according to the

law of gravity, which distributes the pieces as they have been hurled or washed down from the parent rock with a certain amount of regularity—the larger and least weather-beaten ones being nearest the lode—he can leastways observe at what point up the slope the "float" rock ceases to be seen; then he may sink a ten-feet-deep pit, or else drive a crosscut to strike the "body" of that which he is in search of.

Before commencing this, he must take note of the slope on which the "likely" broken away rocks repose, because



FIG. 1.—ILLUSTRATION OF A DEPOSIT PURSUING A CURVILINEAR COURSE.

O, outcrop; the deposit dipping  $60^{\circ}$ . A shaft sunk at A would cut the deposit at Y instead of X, as supposed.

judgment may tell him that the parent rock is not directly under his feet, but rather to the right or left, according to the amount of inclination of the hill-side. Much unnecessary labour is often performed through not taking account of this, as one naturally imagines that the lode is just underneath the line where the greatest amount of "float" occurs, whereas it may in reality be several yards distant, probably on the ridge just a little way off, but decidedly *not* on the other side of it.

Sometimes, as is the case with the Transvaal conglomerate, the direction of a deposit near the outcrop may alter con-

siderably as depth is gained ; and, where no other outcrops at a distance are observable, much wrong calculation as to

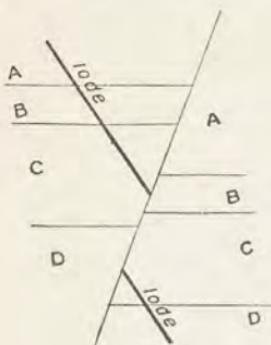


FIG. 2.

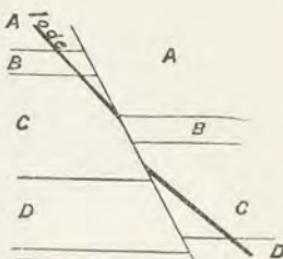


FIG. 3.

future prospecting or sinking of shafts, &c., may be the result. (Fig. 1.)

Where "faults" occur, the course of lodes or beds may be irregular in direction on account of the dislocation of the

country rock ; but if the country is made up of different kinds of layers, the deviation may frequently be easily determined by the relative position of the beds. (Figs. 2, 3, 4.)

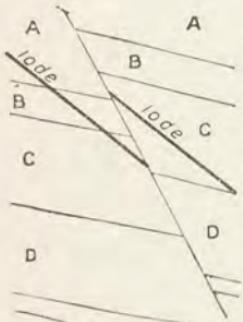


FIG. 4.

In examining the loose rocks on the surface, the expert explorer can often form a tolerably correct notion of the nature of an underground lode, despite the fact that exposure to weather entirely alters a piece of rock which once upon a time may have been metallic in appearance before it became disconnected from its original position.

So, in scaling the heights, he casts his glance in every direction, to observe if the "country rock" be "kindly" for veins, and all the while keeps a sharp look out for that kind of rock known

to form the matrix of a mineral vein. The matrices are chiefly quartz, fluor spar, and calc spar; generally quartz. (See Chap. VII.)

Fluor spar (fluate of lime) is favourable for lead and copper, calc spar for lead and silver; but quartz is very nearly the universal matrix of veins in a mineral country, and thus it is that quartz rock should be especially searched for. Very frequently the pieces of quartz broken away from the lode and also the surface portion of the lode are honeycombed. Having been exposed to the influence of the atmosphere and moisture, most of the metalliferous parts once existing in the cavities, and similar to what one might expect to find a few fathoms downwards on the vein, have been decomposed, and so, instead of filling up the honeycomb cavities of the surface quartz, have merely left traces in the form of stains. This only applies to the metallic portions oxidizable, for it is in the surface of honeycombed auriferous rock that the unmistakable yellow specks may be seen in the cells once filled up with iron or copper pyrites or other metallic compound associated with the precious metal. Gold and silver in the native state (the former very much more so than the latter, which becomes tarnished) weather the effects of the elements much better than most metals, and can be recognised in the native condition; but experience alone can acquaint one with the variously shaded blacks, reds, greens, browns, greys, &c., which the metallic sulphides have left behind as oxides and carbonates. One of the best surface indications is the honeycombed rock brown with iron oxide. In the German mining districts there is a saying—

“Es thut kein gang so gut  
Er hat einen eisernen hut.”

(“There is no lode so good as the one which has an iron hat.”) And this quite corresponds with the French “chapeau de fer,” and the Cornish “gossan.”

The iron oxide is really the result of the decomposition of iron pyrites; and in the lode with this at “grass roots,” iron pyrites would be found deeper down. Having thus traced the honeycombed quartz—the pieces of which are

less angular and smoother the farther away they lie from the lode—or other likely matrix rocks up the hill or mountain side to some outcropping rock (often forming a distinct ridge) from which it has been hurled down, or to where the detached pieces cease to be noticed, the prospector may dig a trench at right angles, if possible, to the lode, in order to examine its character, the nature of the vein and the gangue, and to find the bounding walls, viz. the upper or hanging wall, and the lower or foot-wall, as well as to note the direction or "strike" of the lode; he must notwithstanding, for the sake of accuracy, "sink" a "prospecting shaft" a few feet deeper than the bottom of the trench, as the inclination of the lode near the surface is most misleading, on account of the body of ore having been distorted from its original shape. When once the probable direction of the lode is ascertained, the positions where it is desirable that other pits, lower down or higher up the hill or on the other side of a valley, should be sunk so as to test the continuity of the vein, are settled. Should the prospect of the vein being a continuous one seem favourable, and the surface "assays" turn out well, development of the claim may be attended to.

At the same time, no person should be led away by such a hope as that "the deeper the vein the more payable the ore"; for, as a fact, though certain lead and copper veins do improve by depth, and also very many gold-bearing lodes—for instance, those in Grass Valley, California, which seem to be as rich at 1,000 feet deep as at the surface—very many do deteriorate in value; nor is it prudent to attach too much affection on any particular lode, until the surrounding country has in some measure been examined. Besides, it is now a recognised fact that veins vary in quality and nature according to the strata they pass through.

Even if the prospects look bright, a person who goes in for mining ought not to be too sanguine of success, for mineral veins are most apt to disappoint; frequently do they "pinch out" between hard rocks, or end in a "pocket," or become changed in character and value when least expected. To err on the safe side, it is just as well for a happy possessor to make sure that at least the surface rock

"assays" payably, simply because his money and time are of too much worth to admit of the expensive and sometimes apparently endless labour involved in developing work. A capitalist may risk some of his quickly amassed gains in following up research in the hope of some day increasing his capital, although he quite understands how thoroughly the game is a chance one; but the ordinary miner should avoid uncertainties much more than he usually does.

That a lode carries gold and silver or any other valuable metal in some form or other, is not sufficient data to lean upon in the estimation of its worth. Oftentimes the gold, for instance, is distributed in the form of very fine powder invisible to the eye and covered with a rusty film (due to sulphides or arsenides, oxide of iron or manganese, and sometimes to sulphate of copper and iron); and in consequence, though the "assay" may be favourable, the extraction of the precious metal from the ore by the amalgamation is not satisfactory, as the mercury "sickens" or "flours." Again, the value of a body of ore, though it may be rich in precious or valuable metals, depends in a measure upon the nature of the other constituents, especially when the ore has to be smelted. Antimony or arsenic, in not very great quantities either, may render an otherwise valuable ore useless so far as profitable smelting is concerned. Before digging operations are commenced, the pieces of rock from the lode should be examined, and, if such is possible, by a reliable assayer, who, if he suspects the presence of precious metals, will, by scorification or melting in a crucible, and afterwards by cupellation method, determine the amount of gold and silver per ton of a similar rock, and, without undertaking a careful quantitative analysis of the other associated metallic compounds, will, from the slag in the scorifier or crucible and colour or appearance of the bone ash cupel after the operation is concluded, be able to judge approximately what proportions of the metals copper, iron, lead, antimony, zinc, &c., are mixed with the others. It is always the wisest plan to obtain a proper assay before development work is entered on. Unfortunately, this is not an easy matter in out-of-the-way places. To assay correctly means a course of training; for this reason the author can-

not conscientiously advise anyone to undertake a silver or gold assay by scorification and cupellation, nor a "burette" one for copper, iron, zinc, &c., until he has practised the methods under the eye of an assayer; because in all likelihood his own attempts, though they might be near the mark as to results, would more than probably be quite misleading. Still, there is no reason why an inexperienced person should not attempt to qualitatively test minerals by simple methods, nor in some instances do so quantitatively. To fly to the assistance of a chemist or a mineralogist or an assayer for every little matter of inquiry concerning minerals is not only inconvenient, but in many mining districts unsatisfactory, as there are, naturally, so many unreliable so-called authorities to be met with. Because a miner pronounces such a mineral unlike anything he has seen in Cornwall, or California, or Ballarat, and devoid of any valuable metal, the prospector need not be too ready in accepting such an opinion; for, as a rule, the knowledge of an ordinary miner, expert, perhaps, in certain matters, such as timbering tunnels, &c., is neither remarkably extensive nor always sound. Neither must he depend on the superficial conclusions of any professed expert who has arrived at such by a superficial examination, even with the help of a magnifying glass. Experience abroad tells one that not only has the ordinary miner erroneous notions about such minerals as grey copper ore, silver glance, fine and coarse-grained galena, &c., but also that the most experienced mineralogist cannot for a certainty tell at first sight how much gold or silver may be concealed in a particular rock. Both of these precious metals are found in several places, which many persons might call most unlikely formations, and it is quite a common thing to handle specimen rocks worthless in appearance and yet assaying very high in gold and silver, and also handsome looking specimens that disappoint in not "running" anything to the ton in either of the precious metals. Nor can a person, unless he be a thorough expert, depend upon the appearance of certain pieces of ore for a guide as to the yield of valuable metals. Many of the silicates, carbonates, and chlorides are perfectly unmetallic to look at, and when associated with other metals are very

deceiving as to their real value. For a long time the chloride of silver deposits in Colorado were passed over without their nature being known, and so were the carbonate of lead (carrying silver) unnoticed at Leadville, which, through the discovery, in five years became a city of 30,000 inhabitants. Who would say how much per cent. of nickel there is in a particular piece of the New Caledonia hydrated silicate of nickel ore, or how much silver in the Leadville ore, or what proportion of gold is likely to be in a lump of copper pyrites or iron pyrites, unless he had made each a special study? Therefore it is just as well that a person should be independent of the opinions of others and, to a certain extent, of his own; and, at the same time, never grudge a few shillings or dollars in obtaining the advice of a proper assayer.

Let us now return to the original subject. Supposing that a correct assay of the lode matter has been secured or a rough one made, the prospector has still some items of significant worth to consider before he commences to build "castles in the air," or even continue development work. He must find out if the ground is easily worked (for in one locality though "sinking" through a soft ground may only cost £2 a fathom, "sinking" through hard ground may cost £20 or more); if the ore to be smelted is refractory, or is capable of concentration after sorting, before it is sent away to the smelting or to the crushing and amalgamating works. He must find out exactly the price of smelting or otherwise treating the ore, taking into consideration such items as the cost of labour, the freight of ore and fluxes as well as their cost, the freight of the ores to the "works," &c. He must take into account the proximity or distance off of both fuel and water, as well as the obtainable quantity of each. Many spots in Arizona and New Mexico exist where the working of veins and alluvial diggings is impossible for the time present, or retarded through the absence of creeks and springs. He must remember that a lode running twenty dollars' worth of metals to the ton may be of more value than another running two hundred dollars not very many miles off; that a low-grade silver ore in one locality may be

of more intrinsic worth than a vein of pure silver, having the thickness of a knife blade, in another.

In brief, the character and quality of ore, as well as the probability of the continuity of the lode, the location of the mining claim, the number of acres of available fuel and timber within reach, the proximity and quantity of water, every expense attendant on carriage, smelting operations, &c., should be considered in detail before the development of any single mine merits commencement, in order to turn out a profitable concern. It has been said that in the world there are ten unprofitable mines to one profitable ; so let no one take the trouble to dive into the above considerations until he really believes that there is "payable stuff" to be dug out of his "claim" ; let him avoid the habit of reckoning the value of a property from a few picked specimens.

## CHAPTER II.

### *ROCKS.*

Rocks classified.—Superposition of stratified rocks.—Lamination.—Stratification.—Denudation.—Cleavage.—Joints.—The condition under which metal-bearing deposits are found.—Nature of mineral veins in a lode, &c.—Dip.—Strike.—Clinometer.—Compass.

THE following are the various divisions under which rocks may be classified :—

#### **IGNEOUS.** (Rocks which have been subjected to heat.)

*Volcanic* (those that have been cooled at or near the surface) :—

Trachyte (rough, greyish in colour, and light in weight).

Basalt (blackish or brown, heavier and with fewer holes in it than trachyte). Phonolite, Andesite (of which porphyrite is an altered variety). Dolerite (with crystals more prominent than in basalt) : elvans (including quartz-porphyry) : pitchstone, &c. These last three occur as dykes or intrusive sheets : the two last are offshoots of granite formations.

Obsidian (usually transparent and like bottle glass, pumice, &c.) : rhyolite, &c.

*Plutonic* (those that have cooled at some depth below the surface) :—

Granite, porphyry, syenite, diorite, gabbro, &c. ; these usually have a distinctly crystalline structure, frequently with large crystals.

#### **METAMORPHIC.** (Of igneous and aqueous origin, but which have undergone a change by pressure, &c.)

Gneiss (in composition like granite, but foliated).

Mica schist (quartz and mica), hornblende schist, talc schist, chlorite schist, diorite schist, are some of the foliated forms. Quartzite and some serpentines are metamorphic.

#### **AQUEOUS.** (Deposited by liquid agency.)

Gravel (made up of loose rounded pebbles), conglomerates and breccias.

Grit (in which the grains, usually of quartz, are cemented together).

Sandstone (in which quartz grains are very fine).

Sand (in which the grains are loose).  
 Clay (silicate of alumina and of a plastic nature). Slates (hardened clay, which displays cleavage across the bedding).  
 Shales (hardened laminated clay).  
 Marl (clay containing carbonate of lime).  
 Loam (clay mixed with fine sand).  
 Flint (nearly pure silica).  
 Limestone, chalk, marble, &c. (made up of carbonate of lime).  
 Dolomite (carbonate of lime and magnesia).  
 In addition to these may be mentioned volcanic ash, deposits from hot springs, &c.

With regard to the age of granite, which formerly used to be considered the oldest rock, and also that of the metamorphic rocks, the latter are of various ages, and really



FIG. 5.—GENERAL SECTION FROM THE SIERRA NEVADA INTO CALIFORNIA.  
 1, Granitic and gneissic rocks. 2, Slates and sandstone. 2A, Crystalline and metamorphic rocks, slates, gneiss, and gneissic rocks, in some places quartzite (gold-bearing). 3, Devonian and carboniferous limestones, with shales and sandstones (gold and silver bearing). 4, Coal measures. 5, Triassic rocks. 6, Oolitic. 7, Liassic. 8, Tertiary.

represent certain rocks metamorphosed. It is supposed, from its nature, that granite could not have been subjected to a very great heat (although I have classed it as igneous), and though, while evidence does not deny that the basis of rock formations may be granite, still it shows that the intrusive granitic rocks which are met with in the crust of the earth belong to various ages; and it may be taken for granted that the formation of granite in another geological formation is newer than the rock which it penetrates and older than the strata deposited on it.

Not only are rocks deposited by the agency of water in

the form of strata, but their beds also are made up of thin laminæ, or leaves (Fig. 6), and sometimes the laminæ lie unevenly (Fig. 7).



FIG. 6.



FIG. 7.



FIG. 8.—SYNCLINAL.



FIG. 9.—ANTICLINAL.

Stratification is by no means always horizontal, for the beds sometimes dip considerably, and sometimes have been bent by pressure or strain into curves. When the beds

## SUPERPOSITION OF STRATIFIED ROCKS.

ROCK FORMATION.	COLOUR.	NATURE OF FOSSILS, &c.
RECENT & PLEISTOCENE .	Of many tints.	All sea-shells are of living species ; bones of animals, such as bear, &c. In England 50 per cent. of existing species of shells ; bones of animals abundant. Contains about 80 per cent. of extinct shells ; bones of animals ; plants, &c. Clay, sand, &c. Contains freshwater and marine strata, extinct shells and bones of animals.
PLIOCENE . . .	White, green, red, yellow, and other tints.	In Tertiary rocks yield brick and other clays, gypsum, sand, phosphate of lime deposits, &c. Coal fields of this period occur in India, Indian Archipelago, Philippine Islands, Japan, New Zealand, Vancouver Island, and in some places in Europe.
MIOCENE . . .		Upper chalk, and lower chalk without flints ; chalk marl ; upper greensand. Contains sea-shells, sponges, sea-urchins, &c.
EOGENE. . .		
CRETACEOUS . . .	Generally whitish.	Sand, clay, or marl (containing a few marine species). Clay and sand (used in glass-making). Does not contain marine species, but extensive sub-tropical flora.
GAULT . . .	Dark blue and greenish.	Clayey and calcareous deposits.
LOWER GREENSAND, including WEALDEN . .	Greenish, and other tints.	Clay, sand, limestone, and shales. Consistuous for number of ammonites and nautilus shells. Building and paving stones are obtained from the Oolite and Lias. Alum shale from the Liias ; iron from both Oolite and Liias.
OOLITE } JURASSIC	Yellow, green, white, drab, grey, blue, &c.	Red clays, marls, shales, and sandstones. Contains remains of fishes and reptiles and animal footprints. Contains rock-salt beds in Cheshire.
LIAS, &c. . .		
TRIAS . . .	Red, green, and white.	

PRIMITIVE		
PERMIAN . . . . .	Red, yellow, white, and drab.	{ In England, reddish coloured sandstones and magnesian limestone. Few fossils in the former, but in the latter remains of fish with peculiar sturgeon-like tails. Animal footprints. <i>Coal measures.</i> Contains bands or seams of coals in limestones, sandstones, or shales; also iron ore. Freshwater and marine shells. Enormous amount of fossil plants, such as ferns, trees, club mosses, horse-tails (calamites), &c.
CARBONIFEROUS . . . . .	Chiefly of a dark grey colour, with bluish or black tints.	{ <i>Milstone grit.</i> Coarse and fine sandstone, conglomerate, and shales. Few fossils. <i>Mountain limestone.</i> Contains remains of corals, sea-lilies, and shells, including nautilus, &c. Trilobites are rare in the Carboniferous formations. Limestones, sandstones, and slates.
DEVONIAN . . . . .	Chiefly red with grey and yellow tints.	{ Contains trilobites, though not so plentiful as in Silurian, shells, plants, and animals. Chiefly red, though sometimes purple or green shales, limestone, and conglomerates. Contains remains of freshwater fish.
SILURIAN . . . . .	Grey, red, purple, green, or greenish.	{ Clay strata, slates and shales, sandstones, grits, limestones, conglomerates, &c. Contains remains of trilobites, corals, starfish, graptolites (the modern representative of which is the sea-pen). The trilobites and graptolites are very characteristic fossils. This is the oldest formation in which fossil fishes are found. Volcanic rocks abound in this formation, and the stratified rocks are frequently much tilted up or bent. (See Figs. 11, 12.)
OLD RED SANDSTONE . . . . .	Various colours.	{ Earthy slates, sandstones, flagstones, and conglomerates. Fossils of trilobites, &c. Roofing slates, hones and slabs, and various metallic ores are obtained from this formation.
CAMBRIAN . . . . .	Various colours.	{ Crystalline gneiss with limestone beds and granite veins. In Canada it covers more than 200,000 square miles. From it are obtained building materials, &c., &c.
LAURENTIAN . . . . .	Various colours.	N.B.—The stratified rocks older than the coal measures of the carboniferous formation conspicuously abound in metalliferous veins. So also do the metamorphic and granite rocks. Iron, lead, zinc ores, &c., also are mined for in Carboniferous rocks.

are bent into ridges or troughs for considerable lengths they are called respectively anticlinal and synclinal (Figs. 8, 9).

When one series of strata is parallel to another, the two are said to be conformable; when not parallel, unconformable, as in Fig. 10.

In this illustration the one set of strata (dipping 45°)



FIG. 10.

has been tilted up from its original horizontal position; after which the horizontal strata were deposited.

The wearing away of rocks may be produced by various denuding agents, such as wind, rain, running water, sea, frozen water, &c. Sometimes the water acts chemically and

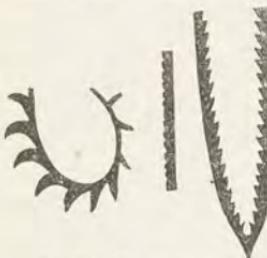


FIG. 11.—GRAPTOLITES.



FIG. 12.—TRILOBITE.

rots the rock, while rivers and rain dig and saw, the sea planes, the expansion of ice splits, and glaciers file it. As to weathering well, the sandstones seem to be less liable to disintegration than most rocks, unless they contain iron or carbonate of lime; limestones are readily attacked by water.

While some rocks can be split along the layers as originally deposited, other fine-grained ones, such as slate, can be most easily so in a direction across the line of bedding. In contorted strata the lines of cleavage are parallel, as in Fig. 15. Cleavage is probably due to lateral pressure.

Most rock masses (from shrinking, in aqueous rocks; and cooling in igneous rocks) are divided into blocks, sometimes quite regularly, by means of what are called joints. Deep in a mine, these joints fit closely; not so at the sur-



FIG. 13 AND 14.—DENUDATION OF STRATA.

face. Most frequently the direction is at right angles to the planes of bedding. In sandstones the joints are irregular, and the blocks of different sizes; in limestone, the joints are fewer than in shale and some kinds of slate, and



FIG. 15.

the blocks are generally cuboidal, the vertical joints being very regular.

The valuable minerals and metal-bearing deposits of the earth are found as—

*Lodes*, the ordinary fissure vein running through various strata, and the gash vein, though wide at the surface, pinching out.

*Beds* of ore, interstratified between other beds. For instance, coal, iron ore (especially in the Oolite formation), copper ore in shale, silver and lead ore in sandstone, &c. Deposits irregularly stratified. Contact deposits between two formations where the deposit lies on the older one, &c.

*Irregular deposits*, such as pockets, &c., which lie sometimes in various formations. Contact deposits, network of veins, and where mineral is diffused through rocks, or in small cracks, or in dykes, or scattered about country rock near the walls of a lode.\*

*Superficial deposits*, such as nearly all the diamond and gold alluvial diggings, stream tin deposits, &c.

With regard to the nature of the veins in lodes, the metal-bearing minerals are scattered throughout the vein stuff, or in nests and strings; sometimes they may be found next to the "hanging" and "foot" walls, or in many cases in regular symmetrical layers between layers of the different substances in the gangue, as in Fig. 16.

The angle which the plane of a stratum or lode makes with the horizon is called the dip; the line where the plane cuts the horizontal plane is called the strike. As it is of paramount importance for the geologist to thoroughly understand the full meaning of these terms, the following explanation will be of use.

If a sheet of note-paper be held so that one leaf is horizontal and the other hangs down, the angle which the latter makes with the former is the dip, and the line where the two leaves are connected is the strike. Suppose the plane of the lower leaf sloped towards the east and made an angle of  $45^{\circ}$  with the horizontal leaf, it would be said to dip  $45^{\circ}$  E., and the strike (which is at right angles to the direction of the dip) would run north and south. The line in which a stratum or lode cuts the surface is called the "out-

\* In composite lodes several veins may run through a formation; so the boundaries of these veins must not be mistaken for the real boundary walls. Between the real walls the whole formation may be metal-bearing.

crop," and where the surface is level the direction of course can be measured by the "strike."

In measuring the dip of a bed, or lode, or slope of a hill, the eye can be of great service in doing so approximately; but an instrument called the clinometer is of more use when accuracy is required. Various kinds of this simple instrument are to be met with, some having a prismatic compass and a spirit level in the same apparatus; the principle,



FIG. 16.—CRYSTALLIZED MINERAL LODE.

- a n*, on each side of the lode, is a band of iron pyrites.
- b b* represents plates of quartz upon the iron pyrites.
- c c* are copper pyrites—the yellow sulphide of copper and iron.
- d d* are bands of quartz and fluor spar.
- e e* are bands of quartz containing veins of copper ore.
- f f* are crystalline layers of quartz, with strings of copper ore.

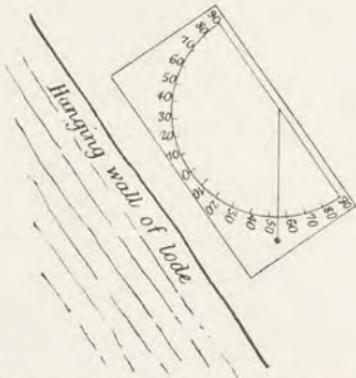
however, is the same in each. A very simple one can be easily made as follows. On a rectangular piece of wood or cardboard describe a semicircle as in Fig. 17. From C, the centre of the whole circle, draw C D at right angles to A B. Divide A D into  $90^\circ$ , and D B into  $90^\circ$ , placing the zero mark at D, and the divisions  $10^\circ$ ,  $20^\circ$ , . . .  $90^\circ$ , as in the illustration. Let a plumb-line, such as a piece of thread with a small weight at the lower end, be suspended from a nail or small pin at C.

Now, when the upper edge is held horizontally, the plumb-line will pass over the zero marking and hang vertically; when held parallel to the line of bedding, or lode, or slope



FIG. 17.

of a hill, the plumb-line will be inclined a certain number of degrees to the fixed line C D, and the number of degrees read on that point of the semicircle over which the plumb-

FIG. 18.—A LODE WITH DIP OF  $55^{\circ}$ , AS SHOWN BY THE CLINOMETER.

line passes will indicate the inclination of the bed, lode, or slope of a hill to the horizon, *i.e.* the dip. A clinometer and compass may be combined in the same apparatus by

fixing a small pendulum to the centre of the compass directly under the magnetic needle.

To use the compass, hold it horizontally in front of the eye, and note the number of degrees which the direction of the line looked along makes with the magnetic north as shown by the needle. The ordinary magnetic compass should be divided into degrees, so that between N. and E. are  $90^\circ$ ; E. and S.,  $90^\circ$ ; S. and W.,  $90^\circ$ ; W. and N.  $90^\circ$ .

Suppose the observer looking along the strike of a lode notices that its direction is  $30^\circ$  from the north towards the east, the direction is said to be  $30^\circ$  E. of N. Although the prospector in his calculations will probably only note his readings from the magnetic north, it may be well to remind him that the magnetic north differs from the true north. If the latter is required at any time it can be found by noticing the shadow which a vertical post casts at noon.

## CHAPTER III.

### *TESTING MINERALS BY THE BLOWPIPE.*

Apparatus required.—How to use the blowpipe.—Nature of the flames.—Methods of testing in an open tube and a tube closed at one end.—On charcoal with carbonate of soda.—With borax and microsmic salt on platinum wire.—Tables of reactions with borax and microsmic salt.—Testing with nitrate of cobalt.—General table (for the qualitative analysis of metallic substances).—Confirmatory tests.—To detect certain common substances associated with metals.—Temporary blowpipe.

APPARATUS required consists of the following :—Blowpipe. Candle or lamp (fed with oil or melted tallow). Forceps with platinum points. Charcoal. Steel forceps. Platinum wire and foil. Magnet or magnetic needle or magnetic knife blade. Knife. Mortar (agate is the best material) and pestle. Borax, microsmic salt, carbonate of soda in small boxes. In addition to the above, a small bottle of hydrochloric acid, and also some nitrate of cobalt solution, will be most useful. A few small open glass tubes, and glass tubes closed at one end. Many other articles might be of great use, such as a small aluminium plate, some nitric acid, sulphuric acid, zinc for confirmatory tests, and also hyposulphite of soda ; at the same time, they are not absolutely necessary.

In testing the quality of a mineral by the blowpipe, a small but well-chosen fragment about the size of a mustard-seed is sufficient.

In using the blowpipe, the principal thing to learn is to blow and breathe at the same time without removing the mouth from the instrument. This is effected by filling the mouth with air and gently blowing, and at the same time by breathing through the nostrils.

A lamp with a large wick, and fed with olive oil or melted tallow, affords a good flame, and so does an ordinary candle with a broad wick.

The blowpipe flame consists of two parts, the blue one

(made up of inflammable gases) and the yellow one. To obtain the reducing flame the blowpipe jet should be just over the wick of the candle or lamp (Fig. 19). The specimen should be kept in the luminous part of the flame for

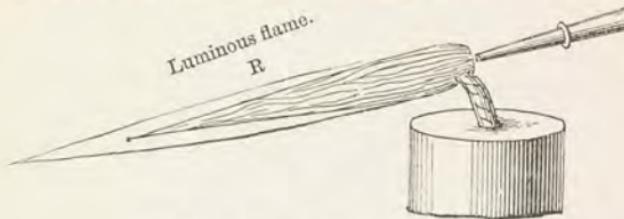


FIG. 19.—R—REDUCING POINT.

some time. To obtain good results in this flame is not always easy to a beginner, who, however, will be more successful with the oxidizing flame. At or beyond the extremity of the yellow one (the whole of the gases being con-



FIG. 20.—O—OXIDIZING POINT.

sumed) bodies are combined with oxygen, and this is called the "oxidizing" flame. To produce it properly, the blowpipe should be placed a little farther into the flame, and the operator should blow more strongly (Fig. 20).

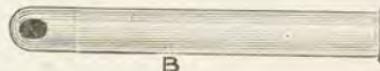


FIG. 21.

Treatment in a tube closed at one end (Fig. 21) is best conducted over a spirit lamp. When the substance is to be heated in an open glass tube (Fig. 22), the tube should be inclined so as to allow a current of air to pass through

(N.B. By heating a point of a straight tube in a spirit lamp, the tube may be bent into the required angle.) The charcoal on which the mineral is to be heated ought to be made from very light wood—such as elder, pine, &c.—and which, when heated, should be as free from smoke and ash as possible.

To treat the substance on charcoal, a small cavity should be bored on the edge of the grain in the top part of the charcoal by means of a knife-blade, and when the blowpipe flame is directed on the specimen, the support should be held in an inclined position, in order that the incrustation deposited on the cool portion can be properly noticed.

An aluminium plate about 4 inches long by 2 broad, and  $\frac{3}{2}$  inch thick, and with half an inch at the end bent nearly

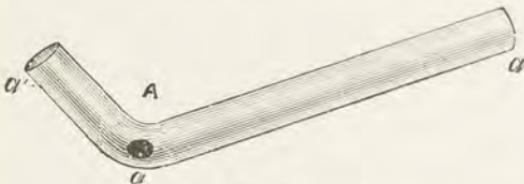


FIG. 22.

at right angles to the other part, and on which the specimen can be rested, is a capital support; only, as the plate is apt to become very hot during an operation, it must be held by tongs, the handles of which are wadded, so as not to come in contact with the operator. In using this support the specimen may be placed on a thin piece of charcoal. The incrustations on the aluminium plate are thicker than those on the charcoal support, and they can easily be experimented on by the blowpipe. When the operation is over, the plate may be cleaned by rubbing it with fine bone ash, by means of a piece of washleather.

Firstly, treat the substance alone on charcoal, and notice the effect of the oxidizing and then of the reducing flame on it. After which, treatment with carbonate of soda, and afterwards with borax and microsmic salt, may be necessary.

As, sometimes, metals cannot be reduced from minerals by simply heating on charcoal alone, carbonate of soda is

made use of. The substance should be very finely powdered and mixed with slightly moistened carbonate of soda, then placed in the cavity of the charcoal, and a gentle heat applied to it in order to drive off moisture ; afterwards the temperature should be considerably increased. Not only must the colour of the incrustation be noticed, but also the fused substance along with some of the charcoal ought to be removed, and ground up with a little water in an agate or porcelain mortar. More water should be added, and the whole mixed up ; the water, together with the lighter matter, should be poured off very carefully, which may be done with the help of a small glass rod or pencil placed at the side of the tilted-up mortar, so as to allow the water to run gradually down the side. The residue at the bottom of the mortar is thus ready for examination, and the metallic fragments, if any, will be seen by the naked eye or a magnifying-glass as glistening spangles or as powder.

When there is no incrustation, the metals—gold, silver, and copper—if present, yield glistening beads, and iron, nickel, cobalt, leave a magnetic grey powder.

Should there be an incrustation, the General Table C must be consulted, though each of the metals—silver, tin, lead, antimony—may be recognised in the residue by its characteristic appearance. As a rule, one ought not to rely upon the treatment with carbonate of soda, rather confirm by that with borax and microsmic salt.

The usual fluxes, borax and microsmic salt, readily dissolve metallic oxides at a high temperature. In order to make sure that the substance is in the state of oxide, it should be exposed to a gentle heat and roasted, in order to drive off sulphur or arsenic associated with metals in the mineral.

To treat with either of these fluxes, bend the end of a small platinum wire round the point of a pencil into a loop of this shape, but smaller in size—

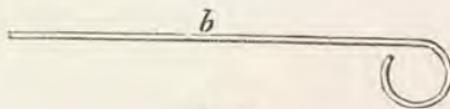


FIG. 23.

TABLE A.

With BORAX.		In Reducing Flame.	
In Oxidizing Flame.			
Bead.	Hot.	Cold.	Cold.
Yellowish.	Colourless.	Grey.	Grey.
Blue.	Blue.	Blue.	Blue.
Green.	Bluish green.	Colourless.	Brown.
Yellow to red.	Colourless to yellow.	Green.	Bottle green.
Yellow.	Colourless.	Grey.	Grey.
Violet.	Reddish brown.	Grey.	Grey.
Colourless.	Colourless.	Grey.	SILVER.
Colourless.	Colourless.	Colourless.	TIN.
Yellowish.	Colourless.	Grey.	ZINC.

TABLE B.

With Microscopic Salt.		In Reducing Flame.	
		With Microscopic Salt.	
In Oxidizing Flame.		Indication.	
Bead.	Hot.	Hot.	Cold.
ANTIMONY OXIDE	Colourless.	Colourless.	Colourless.
COBALT	;	Blue.	Blue.
COPPER	;	Green.	Blue.
IRON	;	Yellow to red.	Colourless to yellow or brown.
LEAD	;	Colourless.	Yellow to reddish yellow.
NICKEL	;	Reddish to brownish red.	Reddish.
SILVER	;	Yellow.	Grey.
TIN	;	Colourless.	Colourless.
ZINC	;	Colourless.	Grey.

With Borax } Hot Yellow } Bismuth or { Violet } Manganese.  
 In O.F. } Colourless } Molybdenum. { Amethystine } granese. } In R.F., cold bead; green, uranium; opaque and brown,  
 molybdenum. In either flame, cold bead; green, chromium.

Moisten the loop, and dip it into either borax or\* micromic salt, and then heat it in the blowpipe flame till the flux is fused. When the head is soft or moist, it must be brought in contact with a very small quantity of the powdered mineral, and then exposed to the heat of the oxidizing flame, and afterwards to that of the reducing flame, the change of colour of the head when hot or cold, and the effect of each flame on it, being carefully observed.

If the substance, after heating, be moistened with nitrate of cobalt solution, and again strongly heated, it may when cool afford some clue to its nature (see Table C).

This reagent is often used for detecting—

{ magnesia, which gives a pale red colour;  
 } alumina, " " blue without lustre.

GENERAL TABLE C.

(For the Analysis of Metallic Substances.)

1. Heat the substance in a tube closed at one end :—  
 Sublimate : white = mercurous chloride, white antimony, &c.  
 " greyish black = mercury, &c.  
 " black, red, on rubbing = cinnabar (sulphide of mercury).  
 " black when hot; red, cold = antimony sulphide.  
 Arsenical minerals, too, afford a sublimate.

2. In open tube :—  
 Sublimate : metallic globules = mercury.  
 „ white fumes = antimony.

3. Alone on charcoal :—  
 Colour of outer flame : green = copper, &c.  
 blue = lead, chloride of copper, &c.

(i.) Metals reduced without incrustation :—

White, malleable bright bead	= silver.
Yellow	= gold.
Red metal	= copper.
Grey powder	= iron, cobalt, nickel, platinum.

(ii.) Metals reduced with incrustation :—	
Incrustations : lemon yellow when hot	= lead.
sulphur yellow when cold	
yellowish when hot	= tin.
white when cold	
orange, when hot	= bis-
lemon yellow when cold	
white (fumes given off on withdrawal of flame)	= anti- mony.
muth.	
	brittle metal.

\* N.B.—Microscopic salt is inclined to froth up and fall off the wire so only a very small quantity must be taken up at once.

Incrustation without reduced metal:—

yellow when hot  
white when cold

} = zinc.

4. On charcoal, with carbonate of soda:—  
Same as in 3.
5. On platinum wire with borax:—  
Consult Table A.
6. On platinum wire with microsmic salt:—  
Consult Table B.
7. Heated on platinum wire moistened with hydrochloric acid:—  
Flame colour: blue = copper (afterwards green), lead, antimony, arsenic, selenium; green = copper, also molybdenum, barium, phosphorus, &c.
8. On charcoal with nitrate of cobalt solution:—  
Green mass = oxides of zinc, antimony, tin, &c., &c.

Confirmatory tests when the mineral has been treated alone on charcoal or with carbonate of soda:—

(i.) When metallic beads or spangles are left:—

**Silver.**—If dissolved in nitric acid, an addition of hydrochloric acid or a solution of common salt will precipitate white chloride of silver.

**Gold.**—If dissolved in 4 parts hydrochloric acid and 1 part nitric acid, a precipitate of purple of Cassius will be obtained when protochloride of tin is added.

**Copper.**—If treated with borax on platinum wire it will give reactions, as in Table A.

(ii.) When a grey or blackish residue is left:—

Heat the residue with borax on platinum wire and note the colour of the bead; compare results with Table A, for COBALT, COPPER, IRON, NICKEL.

(iii.) When the mineral yields an incrustation on the charcoal:—

**Antimony.**—If the scraped-off incrustation be treated with hydrochloric acid and zinc on a piece of platinum foil, a black film of antimony is formed.

**Lead.**—If dissolved in nitric acid, the excess of acid evaporated and a little sulphuric acid be added, a white powder will be formed.

**Tin.**—If dissolved in hydrochloric acid, a grey precipitate is formed when metallic zinc is placed in the solution.

**Zinc.**—If the incrustation be heated with the nitrate of cobalt solution, it becomes green.

To detect certain common substances associated with metals :—

**Alumina.**—This is known by its adhering readily to the tongue when licked. Tested before the blowpipe with nitrate of cobalt, it becomes blue.

**Lime.**—This gives a very bright light when heated before the blowpipe flame. It is infusible even with carbonate of soda, and so differs from *silica* and flinty substances.

**Carbonate of Lime** effervesces when a little hydrochloric or citric acid is dropped on it.

**Magnesia.**—When heated with nitrate of cobalt solution, becomes flesh red.

{ **Soda.**—When strongly heated, gives a reddish yellow colour to the outer flame.

{ **Potash** gives a violet colour to it.

**Sulphur** is known by its characteristic odour when the substance is roasted. If a portion of the heated mineral be placed on a moistened piece of silver, a black stain shows the presence of sulphur.

**Arsenic** is known by its characteristic garlic odour when heated.

All carbonates effervesce in acids.\* (N.B. A limestone rock, which is made up of carbonate of lime, can thus be easily distinguished from a sandstone, &c.)

*Certain silicates*, when acted on by acid and heated, gelatinize.

N.B.—A blowpipe for temporary use may be made thus: Procure a long pipe of glass tube ( $\frac{1}{3}$  inch thick). Hold it horizontally over the flame of a spirit lamp. As the middle part becomes softened pull both ends of the tube horizontally, until the middle part of the tube is about the thickness of an ordinary blowpipe jet. File a notch on the thin part, and snap the tube. Now take one portion and again heat it (a little distance from the nozzle), and bend it so that the nozzle may be inclined at an angle to the longer branch.

\* Citric acid, which can be conveniently carried about as crystals and dissolved in a little cold water, is a most useful re-agent. Nearly every carbonate can be dissolved with effervescence in a cold solution. Spathic iron requires a boiling solution.

## CHAPTER IV.

### *THE CHARACTER OF MINERALS.*

External Characteristics.—Tables for determination of the nature of a Mineral by noting its Colour, Lustre, and Streak.—Specific Gravity.—Hardness.—Crystallization.

In order to discover the nature of a rock, the mineralogist may derive the necessary information by a careful study of its external appearance and characteristics; the form of crystallization, hardness, specific gravity, colour, streak (the colour when scratched, or when rubbed on a piece of porcelain), &c., and also from its behaviour when exposed to the action of chemicals or heat.

When examining a mineral specimen, the prospector is, to a great extent, guided by its colour. He may form a truer estimate by also noticing the lustre and streak. But it must be borne in mind that, for example, tinstone, though usually found of a brownish or blackish colour, is sometimes grey. Its streak, too, is not always brown, but sometimes grey, &c. Cinnabar, too, is usually red, though occasionally brown or brownish-black.

The following table may be of some use in the examination of some of the most commercially useful minerals:—

#### METALS WITH METALLIC STREAK.

	COLOUR.	STREAK.
Gold . . .	Yellow . . .	Yellow.
Silver . . .	White (inclined to tarnish) . . .	White.
Copper . . .	Red . . .	Red.
Platinum . .	Grey . . .	Grey.
Bismuth . .	Silver white (slightly red tinge and inclined to tarnish) . .	Silver white.

Also mercury, palladium, osmium, iridium, lead, antimony, tellurium, &c.

Graphite has a dark steel grey metallic lustre and black metallic streak.

#### MINERALS OF METALLIC LUSTRE.

	COLOUR.	STREAK.
<b>Yellow</b>		
Copper pyrites . . .	Brass yellow (sometimes tarnished)	Greenish black.
Iron pyrites . . .	Yellow . . .	Brownish black
Magnetic pyrites . . .	Between copper red and yellow . . .	Greyish black.
<b>White</b>		
Arsenic pyrites . . .	Silver white . . .	Greyish black.
*Nickel glance . . .	Silver white or steel grey . . .	Greyish black.
<b>Red</b>		
Kupfernickel . . .	Copper red (greyish or black when tarnished) . . .	Pale red.
Arsenical nickel . . .	Pale copper red . . .	Pale brown-red.
<b>Brown</b>		
Brown haematite . . .	Brown . . .	Brown and yellow.
Chromic iron . . .	Brownish black . . .	Dark brown.
<b>Grey or Black</b>		
Specular iron . . .	Dark steel grey . . .	Dark cherry red.
Magnetic iron . . .	Dark iron grey . . .	Black
*Galena . . .	Lead grey . . .	Lead grey.
Antimony sulphide . . .	Lead grey . . .	Lead grey and blackish.
*Grey copper . . .	Grey and black . . .	Steel grey ; black, sometimes brownish
Bellmetal ore . . .	Steel grey . . .	Blackish.
*Copper glance . . .	Black grey . . .	Blackish lead grey.
Cobalt, tinwhite . . .	Tinwhite, grey . . .	Greyish black.
Franklinite . . .	Dark black . . .	Dark brown.
Earthy cobalt . . .	Black or blue black . . .	Blackish.
*Brittle silver . . .	Black or iron grey . . .	Black or iron grey.
*Silver glance . . .	Black or grey . . .	Blackish or iron-grey.
Black oxide of manganese . . .	Iron black . . .	Black.
Sulphide of molybdenum . . .	Grey, like graphite	Grey.
Also several lead and antimony compounds, tellurides, &c.		

Certain micaceous iron minerals, which give a red streak, are somewhat metallic-like in appearance.

\* The streak has a metallic lustre.

## MINERALS OF UNMETALLIC LUSTRE.

	COLOUR.	STREAK.
<b>Yellowish-Brown</b>		
Brown iron ore . . . . .		Yellowish.
Molybdenum ochre, oxides of lead, antimony, bismuth, carbonate of bismuth, &c. have sometimes a yellow tinge.		
<b>White</b>		
Silicate of zinc . . . . .	Whitish (sometimes other colours) . . . . .	Whitish.
Carbonate of lead . . . . .	White or bluish . . . . .	Colourless.
Horn silver . . . . .	Greenish white, pearl grey, &c. . . . .	Grey and shining.
Chloride of mercury . . . . .	Dirty white or greyish . . . . .	Yellowish.
	Sulphate of lead, carbonate of lime, clay, &c.	
<b>Red</b>		
Cinnabar . . . . .	Red . . . . .	Red.
Ruby silver . . . . .	Cochineal . . . . .	Crimson red.
Red zinc ore . . . . .	Bright red . . . . .	Orange yellow.
Cobalt bloom . . . . .	Peach red . . . . .	Paler; lavender.
Red copper ore . . . . .	Red (sometimes iron grey on surface) . . . . .	Brownish red.
	Minerals with silicate or carbonate of manganese in them are sometimes pinkish.	
<b>Brown</b>		
Calamine . . . . .	Brownish . . . . .	Whitish.
Tinstone . . . . .	Brown . . . . .	Brownish.
Zinc blende . . . . .	Brown, brownish-red or blackish . . . . .	White to reddish brown. Uncoloured.
Spathic iron . . . . .	Brownish red. . . . .	Yellowish.
Some varieties of brown iron ore . . . . .	Brownish . . . . .	Red.
Some varieties of specular iron ore . . . . .	Brownish . . . . .	Black.
<b>Black</b>		
Black oxide of copper . . . . .	Black . . . . .	Black.
Black oxide of manganese(submetallic) . . . . .	Black . . . . .	Black.
Ruby silver . . . . .	Reddish black . . . . .	Crimson red.
Tinstone . . . . .	Black . . . . .	Brownish.
Zinc blende . . . . .	Blackish . . . . .	Various.

MINERALS OF UNMETALLIC LUSTRE.—*Continued.*

	COLOUR.	STREAK.
<b>Green</b>		
Malachite . . .	Emerald green . .	Light green.
Pyromorphite . . .	Greenish . . .	White or Yellow.
Also emerald nickel, silicate of nickel, and silicate of copper. Also certain chromium and uranium compounds, certain phosphates and chlorides, arsenate of copper, chloride of copper, silicates of magnesia, &c., on surface nickel ore, green stains may be noticed. Many other minerals, such as silicate of magnesia, have a greenish tinge, also phosphate and chloride of lead, sulphate of copper, and certain phosphates, &c.		
<b>Blue</b>		
Malachite and azurite	Blue . . . .	Bluish.

The specific gravity of a rock can often be approximately known by weighing it in the hand, and comparing it with an equal bulk of some other familiar rock; but to accurately obtain the specific gravity of a mineral, a fragment of it should first be weighed in air, then in water (which can be done by suspending it to the scale of a balance and immersing it in water). The weight in air, divided by the weight in air minus the weight in water, gives the specific

$$\text{gravity. S.G.} = \frac{\text{weight in air}}{\text{weight in air} - \text{weight in water}}$$

But this method is more for the scientist than the ordinary prospector.

The colour and appearance of the line or furrow on the surface of a mineral, when scratched or rubbed, is called the *streak*, which is best obtained by means of a hard tempered knife or a file. If the mineral is soft, it may be rubbed on a piece of rough porcelain. Those parts which have been much weathered should not be chosen.

To discover the hardness of a mineral, it is necessary to try and find out which of the typical specimens of the scale of hardness (commencing with the hardest and proceeding to the lowest) is scratched by it.

## SCALE.

1. Talc (such as soapstone), easily scratched by the finger nail.
2. Rock salt (also gypsum, zinc, &c.), not easily scratched by the nail, nor can scratch a copper coin.
3. Calc spar (transparent), both scratches and can be scratched by a copper coin.
4. Fluor spar; not scratched by a copper coin and does not scratch glass.
5. Apatite, with difficulty scratches glass and is easily scratched by a knife.
6. Felspar, scratches glass and is not easily scratched by a knife.
7. Quartz, not scratched by a knife and easily scratches glass.
8. Topaz, harder than flint.
9. Corundum, oriental emerald, sapphire, &c.
10. Diamond, scratches any substance.

The hardness of minerals that can be scratched by the finger nail is  $2\frac{1}{2}$  or less, and by a copper coin less than 4.

Minerals may often be recognised, or their nature verified, by the crystallization they assume.

The following are the fundamental forms of crystals :—

1. Regular system (called the cubic, octahedral, &c.). In this system there are three equal axes (imaginary) passing through the same point and at right angles to each other.

For examples—

CUBE.

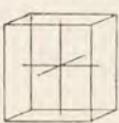


FIG. 24.

OCTAHEDRON.

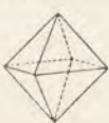


FIG. 25.

TETRAHEDRON.



FIG. 26.

RHOMBIC DODECAHEDRON



FIG. 27.

2. Square prismatic system (has three axes at right angles to one another of which two are of equal length).

## Examples—

RIGHT SQUARE PRISM.



FIG. 28.

RIGHT SQUARE-BASED OCTAHEDRON.

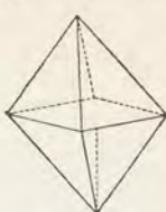


FIG. 29.

3. Right prismatic system (right rhomboidal or rectangular prismatic system), in which the three axes are of unequal length, though at right angles.

4. Oblique prismatic system, which includes the right rhomboidal prism and the oblique rhombic prism. The three axes may be of unequal length while two are at right angles, and the vertical axis inclined to one of these.

Example—Fig. 30.

5. Double oblique prismatic system in which three axes are unequal, and not any at right angles.

6. Rhombohedral system (regular hexagonal system). There are four axes, three of which are in the same plane and inclined to one another at an angle of  $60^\circ$ , the other being vertical: frequently the prism is capped by a six-sided pyramid.

Example—Fig. 31.

Various names are given to the above systems, viz. :—

1. Cubic, regular system, monometric.
2. Square prismatic, tetragonal, quadratic, dimetric.
3. Right prismatic, rhombic, trimetric.
4. Monoclinic.
5. Triclinic or anorthic.
6. Rhombohedral.

Crystalline form is not always sufficient evidence to rely upon in the determination of a mineral, as several different

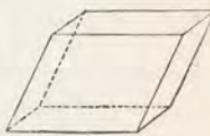


FIG. 30.

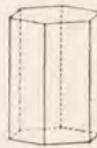


FIG. 31.

minerals assume the same or nearly the same shapes of crystal ; and, again, certain particular minerals are found of more than one shape.

As examples of the first are carbonates of lime, lime and magnesia, zinc, iron, where the angle of the rhombohedral forms only vary between  $105^{\circ}$  and  $108^{\circ}$ .

Sulphur, iron pyrites, specular iron, carbon, are examples of the second kind.

In addition to the already-mentioned characteristics useful in the determination of the nature of a particular mineral, some peculiar properties belonging to certain minerals should be noted.

For instance, some iron, cobalt, and nickel ores are attracted by the magnet ; some minerals—such as fluor-spar, topaz, carbonate of lead, quartz, and calc spar—become electrified by friction ; others—such as calamine—become so when heated. Others, when rubbed, yield a peculiar odour ; some—such as fluor-spar—are phosphorescent, that is, yield a peculiar light when heated ; while many possess a characteristic taste.

## CHAPTER V

### *METALS AND METALLIC ORES: THEIR CHARACTERISTICS.—TESTING.—OCCURRENCE, &c.*

General remarks.—Aluminium; beauxite; cryolite.—Antimony; sulphide.—Bismuth.—Chromium; oxide.—Cobalt; tin white; earthy oxide.—Copper; native; glance; pyrites; grey; ruby; black oxide; silicate; malachite.—Gold; detection of and distinguishing tests; peculiarities; panning out; mechanical assay; sluicing; native gold, &c.—Iron; pyrites; magnetic pyrites; arsenical pyrites; haematite; magnetic iron ore; brown iron ore; franklinite; vivianite; copperas; spathic ore.—Lead; galena; carbonate; pyromorphite; chromate; sulphate; rough method for obtaining lead from galena.—Manganese; black oxide, wad, &c.—Mercury; native; cinnabar; chloride; selenide; to obtain metal from ore.—Nickel; kupfernicket; white; emerald; hydrated silicate.—Platinum; native.—Silver; native; brittle ore; glance; horn silver; ruby ore; silver in carbonate of lead.—Tin; tinstone; bellmetal ore.—Zinc; calamine; silicate; red zinc ore.

As mentioned before, in the last chapter, any one who searches for useful minerals is chiefly attracted by their colour; the lustre, and perhaps streak, may assist him in the determination of their nature. Still, doubts may suggest further investigation. The hardness and the specific gravity may guide him, though it must be confessed, in the case of small minerals, it is no easy matter to accurately find out the latter. Even then recourse may have to be had to what in many cases is really the most satisfactory way of solving the question, namely, to tests by means of the blowpipe or by chemicals. In the following pages is given an account of the principal useful ores—comparatively few in number—including a description of their characteristics and behaviour in the blowpipe flames and with certain chemicals, also of the country rock in which the lodes or deposits occur.

As a general rule, the ordinary prospector concentrates his attention to the discovery of the precious metals, gold

and silver (usually the former). Perhaps he keeps a lookout for lead and copper ores, but very seldom (even when in a granite country) thinks about searching the streams for tinstone or the hills for tin-bearing lodes. He may pass by, or even handle and throw aside, such unmetallic-like minerals as some of the silicates, carbonates, chlorides, &c., simply because of their lightness of weight, or because they do not come up to his notions about what a metal-bearing rock should be. He may even discard some of the heavy minerals on account of their nature being disguised by the presence of iron oxide, which may give them the appearance of an iron ore. Hence the desirability of examining carefully all sorts of minerals and submitting them to tests.

Although in this chapter many of the different metallic compounds are described, it would be well if the prospector made himself especially well acquainted with the appearance of the various oxides, and in a lesser degree with the carbonates, chlorides, &c. The sulphides which are found deep down a lode become chiefly converted to oxides on the surface. Take, for instance, a lode in which copper pyrites and iron pyrites exist several fathoms down. On the outcrop there would probably be the rusty colour due to iron oxide; and black oxide (perhaps the red) of copper, and also the green or bluish stain of carbonate of copper might be distinctly noticed. Still, whether the prospector comes across oxides, carbonates, chlorides, sulphides, or metal in the native state, recourse to the following pages may, perchance, help him to solve the question as to what the true nature of the particular mineral is.

### ALUMINIUM.

This metal is not found in the native state, but in combination with silica, oxygen, fluorine, &c.

Corundum, sapphire, and ruby are nearly pure alumina (oxide of aluminium). Emery is a more impure variety. The silicate is very abundant and is a constituent of the older rocks, of all clays, &c. The presence of alumina is known by heating the substance in the B.F., then moistening it with nitrate of cobalt solution and again heating. A blue, lustreless colour will indicate the presence of alumina.

thus distinguishing it from magnesia in a mineral (see p. 29).

The principal ores besides corundum (H. 9), found in great quantity in crystalline rocks in America, and from which aluminium is extracted, are—

#### **Beauxite.**

Of various colours. Sometimes made up of concretionary grains. Also as clay (sometimes coloured by iron oxide).

S.G.—2·55.

Contains sometimes more than 50 per cent. of alumina (or more than one-third aluminium), the rest being sesquioxide of iron, silica (in small quantity), and water. Is soluble in sulphuric acid.

#### **Cryolite.**

A semi-transparent, brittle mineral.

*Colour*—whitish yellow, reddish, or black.

H.—2·5 ; S.G.—3.

Is a double fluoride of aluminium and sodium, and contains sometimes 13 per cent. of aluminium. Easily fusible in candle flame.

Beauxite is chiefly found near Arles, in the south of France. A rather similar clay has been found in Ireland.

Cryolite is obtained in Greenland (in gneiss), also in America.

Aluminium is of a white colour, easily polished, adapted for casting into moulds, does not become tarnished on exposure to the atmosphere, and hence is suitable for very many purposes.

#### **ANTIMONY.**

The metal is usually found combined with sulphur, arsenic, or sulphur and lead. If a mineral be supposed to contain antimony in any form, the presence of the metal may be known by treating the specimen with carbonate of soda on charcoal in the R.F.\* of the blowpipe, when, if it

\* (*N.B.—O.F. = Oxidizing Flame; R.F. = Reducing Flame; B.F. = Blowpipe Flame; S.G. = Specific Gravity; H. = Hardness.*)

be present, a bluish white incrustation is formed, which (being volatile) disappears when exposed to the O.F. and R.F.; in the latter case with green coloration. The bead is white and brittle. To confirm :—Scrape the incrustation off and treat with hydrochloric acid and zinc on platinum foil. A film of antimony will be left on the latter. If a piece of ore containing antimony be heated in an iron spoon, white fumes will rise and coat the rim. The behaviour of antimony with borax or platinum wire before the blowpipe flames is, when cold, in O.F. = colourless,  
in R.F. = colourless to grey.

Combined with lead, or bismuth, or copper, other tests have to be resorted to.

Antimony is a most undesirable metal to be associated with other metallic compounds in a vein, as it interferes with the ordinary smelting processes.

#### Sulphide of Antimony (*grey antimony*).

The ore from which the antimony of commerce is extracted—

*Crystallization*—right rhombic prisms.

*Colour*—lead grey.

*Streak*—lead grey and blackish.

*Lustre*—shining and metallic.

*Structure*—brittle : thin laminae slightly flexible.

H.—2 ; S.G.—4·5 to 4·7.

*Composition per cent.*—antimony, 73 ; sulphur, 27.

Fuses in the flame of a candle. Before B. flame and on charcoal yields white fumes with odour of sulphur. When pure, is soluble in hydrochloric acid. The oxide—yellow, white, grey, or brown—is sometimes found on the outcrop of a sulphide-bearing lode. Can be distinguished from an ore of manganese, like in appearance, by its being easily fused and its diagonal cleavage.

There are about ten varieties of this last ore, the streaks of which vary ; all the ores, however, are soft, and can be scratched by the finger nail. Grey antimony occurs with ores of silver, lead, zinc, or iron, &c., and is often associated with heavy spar and quartz. Found in metamorphic and

igneous rocks. If antimony sulphide is heated in a glass tube closed at one end, a sublimate, black when hot, reddish-brown when cold, is formed near the test-piece.

### BISMUTH.

Found chiefly in the native state, but also in combination with sulphur, oxygen, tellurium, carbonic acid, &c. It yields a yellow incrustation in the O.F. of the blowpipe.

The oxide, sulphide, arsenide, combined sometimes with copper, lead, &c., vary in colour, hardness, and specific gravity. Bismuth glance, containing 81 per cent. of the metal, is usually of a lead-grey colour. When heated in a closed tube yields a sulphur sublimate. On charcoal before the B.F. sputters and deposits a yellow incrustation leaving metallic bismuth. Oxide and carbonate of bismuth (generally of a yellowish, though sometimes grey, greenish white, &c.) is often found at the surface of a bismuth-bearing lode. In Wales and elsewhere bismuth sulphide is sometimes found in gold-bearing ore.

### CHROMIUM.

The oxide is chiefly found with iron, as chrome iron.

*Colour*—brownish black.

*Lustre*—submetallic.

H.—5·5; S.G.—4·5.

Before the B.F. yields a green bead with borax. Chromate of lead is rarely found. Occasionally an emerald green incrustation is found on chrome iron ore.

Chrome ochre is of a yellowish green colour. Chrome iron is frequently found in a serpentine-rock country.

Chromium compounds are often associated with nickel and cobalt ores.

### COBALT.

Compounds of cobalt, when heated on charcoal before the B.F., yield whitish metallic spangles, which can be attracted by a magnet. The metal moistened on paper with nitric acid gives a red solution, which with hydrochloric acid affords a green stain on drying.

Treated with borax in either B.F. it yields a deep blue bead. Before testing, metallic compounds should be roasted, to drive off volatile matter.

**Tin White Cobalt.**

*Crystallization* — octahedral, cubical, and dodecahedral, &c.

*Breaks* with uneven and granular fracture.

*Colour* — tin white and greyish.

*Streak* — greyish black.

H.—5·3; S.G.—6·4 to 7·2.

*Composition* — cobalt and arsenic.

Before the blowpipe it colours borax and other fluxes blue. Affords pink solution with nitric acid.

**Earthy Oxide.**

Usually massive.

*Colour* — blue black or black.

H.—1 to 1·5; S.G.—2·2 to 2·6.

*Composition* — oxides of cobalt and manganese.

**Cobalt Bloom.**

*Lustre* — pearly.

*Colour* — peach red, crimson; sometimes grey or greenish.

*Streak* — paler; powder-lavender.

*Composition per cent.* — oxide of cobalt, 37·6; the remainder, arsenic and water.

Gives off arsenical odour when heated. Behaviour with fluxes in the B.F. same as other cobalt ores.

In Great Britain cobalt ore is found in cavities in limestone of the carboniferous age. In Norway and other countries a variety of tin white cobalt is found in gneissic and primitive rocks. In Germany deposits of cobalt are found in limestone over copper slates. Cobalt and nickel ores are often met with in the same lode.

**COPPER.**

If a specimen is supposed to contain copper, it should be examined either by means of the blowpipe or chemicals.

With carbonate of soda on charcoal before the B.F., nearly any copper ore is reduced and a globule of metallic copper obtained. Heated with borax or microsmic salt in the O.F. there results a green bead when hot, a blue one when cold. Most copper compounds, when heated in the inner flame,

impart a green colour to the outer one. Copper compounds are, for the most part, soluble in nitric acid. If a piece of polished iron or the bright point of a penknife be dipped into the acid solution, it will be slightly coated with metallic copper if any exist in the ore. Ammonia added to an acid solution affords a green colour, and, in excess, a blue one. Many copper minerals can be dissolved in citric acid, some in cold, others in a boiling solution, and afford a greenish colour. A penknife blade (clean, placed in the solution is covered with a copper film. Some, such as copper pyrites, may be dissolved in a boiling solution of citric acid and nitrate of soda. In the absence of a blowpipe or chemical apparatus, the presence of copper in a substance may be detected in this way:—First, roast the mineral and drop it, when hot, into some grease and expose it to the heat of a flame, which will show a green colour if copper exists. Or, if the mineral be well powdered, mixed with some fat and salt, and placed in the fire, the presence of copper will be known by the blue or green colour. If the powdered mineral be mixed with a little charcoal and roasted for an hour, and then vinegar be poured on it and allowed to remain for a day or so, copper will produce a blue colour, afterwards becoming green.

In a copper-bearing lode the black oxide, sometimes red oxide and green carbonate, may be noticed in the cavities of the surface quartz.

#### Native Copper.

Found in treelike, mosslike, threadlike shapes, in octahedral crystals, grains, &c.

*Colour*—copper red.

Is ductile and malleable.

H.—2·5 to 3; S.G.—8·5 to 8·9.

Can be tested by the blowpipe or chemicals like other copper ores. Usually carries silver. Found chiefly in North and South America, also in Cornwall, Wales, &c.

#### Copper Glance (*vitreous copper ore*).

*Crystallization*—rhombic prisms. Is slightly sectile.

*Colour*—blackish grey, tarnishing to blue or green.

*Streak*—blackish grey, sometimes shining.

H.—2·5 to 3; S.G.—5·5 to 5·8.

*Composition per cent.*—sulphur, 20·6; copper, 77·2; iron, 1·5.

Before the blowpipe gives off sulphur fumes, fuses easily in the outer flame, and boils, leaving a globule of copper. Is fusible in a candle flame. Is rather like sulphide of silver, but the button left after exposure to B.F. shows the difference. If the mineral be dissolved in nitric acid, and the point of a penknife be placed in it, a slight copper coating will be formed if the metal is present, whereas, if a piece of bright copper be placed in it, a slight coating of silver will be formed if silver be present.

#### Copper Pyrites (*chalcopyrite*).

*Crystallization*—tetrahedral, also massive, &c.

*Colour*—brass yellow, sometimes tarnished and iridescent.

*Streak*—greenish black and unmetallic.

H.—3·5 to 4; S.G.—4·15.

*Composition per cent.*—sulphur, 34·9; copper, 34·6; iron, 30·5.

In a glass tube closed at one end it decrepitates, and a sulphur sublimate is left.

Before the B.F., it fuses to a metallic globule. If fused with borax, metallic copper is the result. Tested in acid, like other copper ores. Is sometimes mistaken for gold, iron pyrites, or tin pyrites; but it crumbles when cut, whereas gold can be cut in slices. Is of a deeper colour than iron pyrites, and yields easily to the knife, nor does it strike fire like iron pyrites. It may be distinguished from tin pyrites by the blowpipe and other tests. If the ore be hard and of a pale yellow colour, it is considered to be poor in copper.

Variegated copper pyrites (containing 60 per cent. of copper) is of a pale reddish yellow colour.

#### Grey Copper (*tetrahedrite*).

When containing silver, Fahlerz.

*Crystallization*—tetrahedral, &c.

*Structure*—brittle.

*Colour*—between steel grey and iron black, sometimes brownish.

*Streak*—between steel grey and iron black, sometimes brownish.

H.—3 to 4; S.G.—4·75 to 5·1.

*Composition per cent.*—copper, 38·6; sulphur, 26·3; antimony and arsenic, zinc, iron, silver, &c.

It sometimes contains 30 per cent. of silver in place of part of the copper. After roasting, yields a globule of copper before the B.F. When powdered and dissolved in nitric acid, the solution is brownish green. The ore can be distinguished from any silver ore by the blowpipe and chemical tests. The darker the colour the less arsenic in it.

#### Red Copper Ore (*ruby copper*).

Found massive, earthy, granular, &c.

*Crystallization*—octahedral, and dodecahedral.

*Structure*—brittle.

*Lustre*—adamantine, or submetallic. Is subtransparent or nearly opaque. Detached crystals look rather like spinel rubies.

*Colour*—deep red, ruby colour, though it is often iron grey on the surface.

*Streak*—always brownish red.

H.—3·5 to 4; S.G.—6.

*Composition per cent.*—copper, 88·78; the remainder oxygen.

Heated in a tube closed at one end, it darkens. Yields globule of copper before the blowpipe. Dissolves in nitric acid. Soluble in ammonia: solution eventually azure blue.

#### Black Oxide of Copper.

Usually found on the surface, due to the decomposition of a sulphide or other copper ore. Black copper at the top of a lode may indicate some other copper compound deeper down. If the dusty powder be rubbed between the fingers and dropped on a flame, the latter will be coloured green. Soluble in ammonia: solution azure blue.

**Silicate of Copper.**

Usually as an incrustation, massive, &c.

*Colour*—bright green and bluish green.

H.—2·3; S.G.—2 to 2·3.

*Contains* 40 to 50 per cent. of oxide of copper.

Is rather like malachite in colour, but when dissolved in nitric acid a precipitate is left, whereas malachite is quite dissolved.

**Malachite (*green carbonate of copper*).**

Found in botryoidal or stalactitic masses, and as an incrustation, &c.

*Structure*—fibrous.

Nearly opaque.

*Colour*—emerald green.

*Streak*—a paler green than the colour.

H.—3·5 to 4; S.G. 3·6 to 4.

*Contains* about 57 per cent. of copper.

Before the blowpipe it becomes blackish. With borax before the B.F. it forms a green globule, and eventually yields a copper bead.

Completely dissolves in nitric acid, and so differs from other ores of a similar appearance.

The *blue carbonate* is very like the above; but its crystallization is a rhombic prism, and its streak bluish.

It is impossible to enumerate more than a few of the localities where copper ore is found and its manner of occurrence. It occurs in rocks of every age and in both lodes and deposits. The usual ore in a copper lode is pyrites, which is decomposed into black oxide at the surface. In Cornwall the copper lodes, which generally run east and west, are more productive in the slates than the granites. The New Red Sandstone of Cheshire and Shropshire contains certain deposits of copper, chiefly malachite; and in the Carboniferous Limestone of Shropshire are also deposits of the same ore as well as pyrites. Copper pyrites veins traverse green slates and porphyritic rocks in the north of England. Not to mention the variety of lodes which run through rocks of various age of North America,

the following are a few examples of the position of certain deposits.

In the Eastern States there are deposits in the New Red Sandstone, also in the Carboniferous Limestone and Silurian rocks. In the Lake Superior district, where so much native copper is found, deposits occur in sandstones and shales, underlying greenstone, &c. There are also lodes running through the various strata. Deposits of ruby copper ore occur in Arizona between quartzose and hornblendic rocks and limestone. Lodes and deposits in Chili are worked in hornblendic and felspathic quartz rocks. The celebrated Burra Burra mine in Australia, from which splendid lumps of malachite are familiar objects in museums, consists of an immense irregular deposit of malachite and other copper ores in limestone and harder rocks, as well as in the soil. Copper deposits occur elsewhere in schistose, hornblendic, quartzose rocks, &c., and pyrites-bearing lodes through rocks of various ages.

Copper sulphides (with or without antimony, arsenic, &c.) often occur in gold and silver-bearing lodes; and, therefore, though neither free gold nor a silver compound may be noticed on the outcrop, assays should certainly be made.

**GOLD.**

To detect free or native gold in a piece of specimen rock, in sand or gravel, the sample should be carefully examined by means of a magnifying glass, if the eye is insufficient. The particles of gold, if present in the free state, will probably be distinct, whether wet or dry, and can easily be distinguished by an expert from discoloured mica, iron, or copper pyrites. The usual colour of the metal is well known: but it must be borne in mind that in some localities, such as in New South Wales, Australia, and Costa Rica, it is often found of a very light colour; indeed, sometimes it looks like not very yellow iron pyrites. Gold presents the same colour from whatever direction it is looked at. To the prospector this is a guiding test. If a gold grain be detached from a rock, or selected from sand or gravel, it can be flattened out by hammering and can be cut in slices, whereas those substances likely to be mistaken for gold are reduced to powder when pounded. Iron pyrites is too hard to be cut by a knife, while copper pyrites affords a greenish powder. Besides, pyrites ore, when heated, gives off a sulphury odour. Mica, which when discoloured may be frequently mistaken for gold, is not sectile, and has a colourless streak; it can thus be distinguished from the precious metal. It may be well, too, to know that a speck of gold is not altered in colour or appearance by hydrochloric acid. As the quantity of gold in rock is usually very small—and to be payable it need not be otherwise—the most and only accurate way of determining its quantity is by means of scorification or fusion in a crucible, and afterwards by the cupellation process. This, however, is not always practicable in an out-of-the-way place, and, consequently, more simple means are generally sought for by prospectors in order to obtain a rough assay; and as gold is usually, though not always, met with in the pure metallic state, such are to be in a great measure depended upon. At the same time, it must be remembered that frequently the gold occurs as a very fine powder, invisible to the eye or even under a magnifying lens, and also that the grains—probably due to sulphur of arsenic—may be coated with a

film, which prevents them from being recognised, and also from being capable of amalgamation with mercury until they have been roasted or undergone some operation.\*

To "pan out" gold-bearing matter, the gravel, sand (or rock powdered but not too finely), is placed in a flat bottomed basin or pan, the diameter of which is about a foot, and two or three inches wider at the top than at the bottom. The pan, three-quarters full of ore, should be placed at an inclined position under water, or else water poured into it, and by shaking and agitating the contents of the pan by a kind of oscillatory motion, the lighter portions of the ore are allowed to run over the side of the vessel, until, after much washing, the heavier particles, such as gold, iron sand, &c., settle at the bottom. The iron sand, if magnetic, can be separated from the yellow metal by a magnet, or else can, when dry, be blown away by a gentle blast of air. In Brazil a wooden vessel (a "batea") serves for the "pan."

A little preliminary practice in "panning out" will be of use to any one who anticipates actual work.

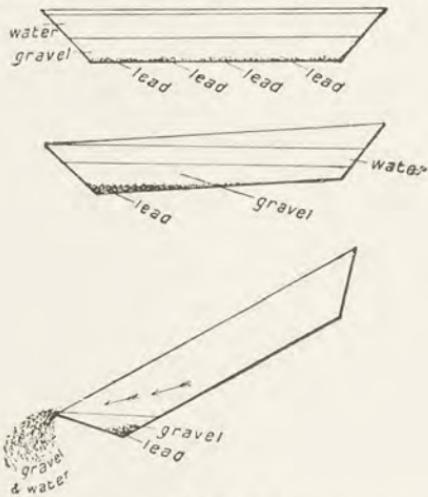
Place some powdered lead (or copper or iron pyrites) with a good quantity of gravel or sand. Wash the whole with water so that all soluble or easily suspended matter may be got rid of, and thereby the separations may be more clearly observed. Now fill the pan with a fresh supply of water, and shake the whole round about, and chiefly from side to side several times, to allow the heavier matter to settle down (and out of view) underneath the gravel. By tilting the pan a little away from the body, and still shaking it, the lead will still seek the lowest level, and the water may be made to wash some of the gravel over the rim (Fig. 35). By several repetitions of these processes a skilful operator will be able to get rid of all the matter except the lead.

Supposing, however, that the beginner lacks the proper adroitness, or is afraid of washing away the lead, he need not carry the operation so far. But if, towards the last stage, he finds a small quantity of, though sufficient, gravel to entirely conceal the presence of the metal, then, by tilt-

\* All large stones or large grains should be removed from gravel and sand, and clay should be well broken up and finely divided in the water, before "panning out" is commenced.

ing the pan to one side and away from the body, and allowing the little water to flow a few times in one direction round the bottom of the pan and over the gravel, some of the gravel will be washed along with the water, and the metallic matter will remain behind (Fig. 36). If such trials are successful with copper (s. g. 8·75) and lead (s. g. 11·35), they certainly would be with gold (s. g. 19·35).

When the gold is of so fine a nature as to float, the operator should pour water on the floating particles, so that



FIGS. 33, 34, 35.

The arrows denote the direction of the flow of water.

their upper surface would no longer be dry ; thus some of the gold might sink to the bottom of the "pan."

The following is another method of obtaining the free gold from a quantity of ore ; and it may be noted that the surface quartz with iron or other stains (which signify sulphides deeper down the lodes) may be tried for gold by the amalgamation process.\* Finely powder a quantity of ore along with water. Add mercury, at the rate of about 1 oz.

\* Quartz, if placed in the red hot part of a fire for a few minutes, and then thrown into cold water, can afterwards be quickly powdered.

of mercury to 8 lbs. of ore, and, if obtainable, a little cyanide of potassium. Grind the whole for two or three hours until the gold and mercury thoroughly amalgamate. Add water, and when the amalgam has settled at the bottom of the vessel pour the lighter matter off, collect the amalgam and squeeze it through chamois leather. The residue must be heated to drive off any mercury remaining, or if the amalgam be treated with nitric acid, the mercury will be dissolved and the gold left.

An addition of a little sodium will assist the amalgamation and prevent loss due to "flouring."

Sometimes as much as 30 per cent. of what ought to be the proper yield is lost in the tailings in a free milling ore.

On alluvial diggings, the operation of washing the gold dirt is usually conducted by means of sluices, having an inclination of a very slight gradient. These sluices consist of a series of troughs formed by planks nailed together, the length of each being about 10 or 12 feet, the height 8 inches to 2 feet, the width 1 to 4 feet. By making one end of the bottom plank of each trough 4 inches narrower than at the other, the troughs can be telescoped into one another, and so a sluice of very great length can be formed. Across the inside of the bottom planks small narrow strips of wood, 2 inches or so thick, and 3 or more inches wide, are fixed across, or sometimes at angles of  $45^{\circ}$  to the side of the trough, at short intervals apart. Running water washes downwards the earth thrown into the sluice, which is open on the top side, and the gold dust accumulates (sometimes assisted by the aid of mercury allowed to trickle out of a vessel from riffle to riffle) in front of the bars, while the lighter matter is washed downwards.

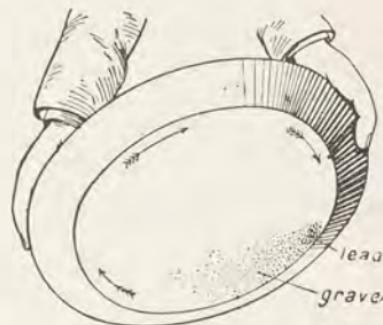


FIG. 36.

### TELLURIDES IN GOLD ORES.

The tellurides have usually a light grey colour, though some are dark grey and some have a slightly yellowish tint, are usually brittle (though one is sectile), and sometimes scaly, or film-like; and all have a metallic appearance. The specific gravity of the most valuable is high, viz.: 7 to 10. Most can be scratched by the nail, and all by a copper coin.

Before the blowpipe, a brilliant greenish-blue luminosity is distinctly seen near the test-piece. When boiled in sulphuric acid, a telluride imparts a pinkish colour to the liquid, which becomes greyish if water be added afterwards. A telluride can usually be soon fused to a globule.

### Native Gold.

Found as grains; laminæ, sometimes threadlike; nuggets, etc. There is always a small amount of silver in the gold

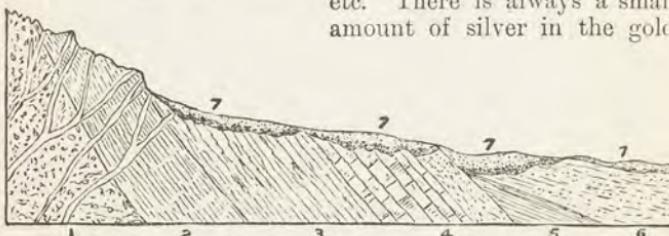


FIG. 37.—SECTION SHOWING THE TWO CONDITIONS UNDER WHICH GOLD IS USUALLY FOUND.

1, Granitic and gneissic rocks, often containing gold finely disseminated. 2, Micaceous, talcose, and argillaceous veins containing gold. 3, Silurian and Devonian strata. 4, Carboniferous limestone and grits. 5, Coal measures. 6, Permian and newer rocks. 7, 7, 7, 7, Drift filling hollows in rocks, with gold, especially at the base of the drift.

(sometimes, as in California, nearly 10 per cent.), and frequently other metals.

*Colour*—yellow.

H.—2·5 to 3; S.G.—12 to 20.

With carbonate of soda or charcoal before B.F. it yields a yellow bead, easily hammered out or cut. If the powdered ore be dissolved in aqua regia (4 parts hydrochloric and 1 part nitric acid), a purple precipitate will be formed,

when protochloride of tin is added to the solution ; or a dark brown powder (really pure gold) will be precipitated when a solution of sulphate of iron (copperas) is added.

Gold, nearly invariably in a native state, is very widely distributed over the globe, and is obtained from the gravel, sand, clay, "drift beds," washed down from gold-bearing strata (sometimes the rich part of the deposits has brown ferruginous matter associated with it), or else from quartz lodes traversing the older slaty and metamorphic rocks and less abundantly in granite. It is also found scattered about in rocks of a granular nature.\* The ordinary gold-bearing lodes and deposits occur as represented in Fig. 37, which represents the structure of the Ural Mountains. Iron pyrites, copper pyrites, magnetic iron, blende, galena, &c., are some of the metallic minerals often very commonly associated with gold in a lode, the iron pyrites in veins of a gold-bearing district nearly, if not always, containing a certain amount of the precious metal. On the surface of a lode the gold specks may perchance be noticed, by the eye or lens, in the cavities of the brown honeycombed quartz rock, although free gold may be invisible in the pyrites rock deeper in the lode and unexposed to atmospheric and other changes affecting the surface portions.

Taking for granted that gold is found under the usual circumstances heretofore mentioned, one must remember it has been payably obtained in unexpected ways : for example, in sinter, in trachyte, in very peculiar conglomerates, &c. Usually the discovery of alluvial gold leads to that of lodes in the neighbourhood ; but because gold deposits are not found, it does not follow that the country is non-auriferous. So, too, because gold is not noticed in the outcrop of a lode, it does not follow that the lode is necessarily an unprofitable one.

It would be out of place here to discuss the theory of how gold in veins was originally formed. In alluvial deposits the grains are usually worn into shape, and so in some other deposits. But it may be remarked that in certain conglomerates the gold is found in thin plates, a fact which suggests that the law of gravity does not apply to the dis-

\* Such as granite, diorite, gabbro, &c.

tribution of the metal in these as it usually does in most deposits where the portions nearest the bed-rock are richest. Here, too, it may be mentioned that in conglomerates, such as the South African, the gold is not chiefly in the pebbles, but in the matter which binds them together.

Nearly every country in Europe has yielded gold under the usual circumstances, in deposits and veins in rocks older than the carboniferous formations, in metamorphic rocks, &c.

The precious metal has been found—not generally very lucratively—in the muds and sands of such rivers as the Danube, Elbe, Oder, Weser, Rhine, and in many of the lesser rivers, and consequently some parts of the hill districts through which they pass contain auriferous rocks. Austro-Hungary is rich in lodes (the gold being sometimes found as a telluride), and the extent of the gold-bearing alluvial deposits of the Ural Mountains is enormous. (See Fig. 37.)

In the British Isles gold is found in various parts of Scotland, in Ireland, in Cornwall, Devon, Lancashire, and more especially in Wales. In North Wales not only has it been gathered from the beds of rivers and sand on the seashore, but has been and also is being obtained from lodes (one of which was worked by the Romans). The auriferous quartz reefs (carrying iron pyrites, galena, &c.) run through slates of the old fossiliferous rocks (Lower and Upper Cambrian), and at the intersection of these gold-bearing lodes with other copper and silver bearing ones the reefs are sometimes rich.

The Western States and territories of North America (especially California), some of the Southern States of North America, Canada, Nova Scotia, British Columbia, Central America, Chili, Venezuela, Brazil (some of the mines have for ages back been worked very lucratively), Australia (Queensland, Tasmania, South Australia, Western Australia, New South Wales, and especially Victoria), New Zealand, West Coast of Africa, South Africa, India, &c., Borneo, New Guinea, Philippine Islands, Ceylon, Madagascar, Persia, and others unmentioned, are all gold-bearing countries.

Some of the conditions in which gold is met with in a few of the leading places are herewith given.

## AUSTRALASIA.

*Victoria*.—In quartz reefs, mostly through lower Silurian rocks, and a lesser number through Upper Silurian. The direction of the majority of the first set is W. of N., that of the remainder E. of N. Not only have the ordinary alluvial deposits, as generally found near the surface in drifts washed down from the gold-bearing lodes in the higher land, being extremely rich, but also (as in some parts of California) the beds of ancient streams which have been covered by other aqueous deposits over which lava once flowed. The following diagram will exemplify the position of such a rich “gutter” :—



FIG. 38.—SECTION OF THE OLDER DRIFTAL GOLD DEPOSITS NEAR BALLARAT.

Scale : Hor.  $1'' = 10$  chains ; Vert.  $1'' = 320$  feet.

a, Drift. b, Basalt. c, Black and red clays. d, Basalt. e, Light coloured clays. f, Basalt. 1, 1, 1, Auriferous drift.

The saddle reefs of Bendigo lie between such strata as sandstone and sandstone, or sandstone and slate ; and are met with chiefly at anticlines, tapering out in depth.

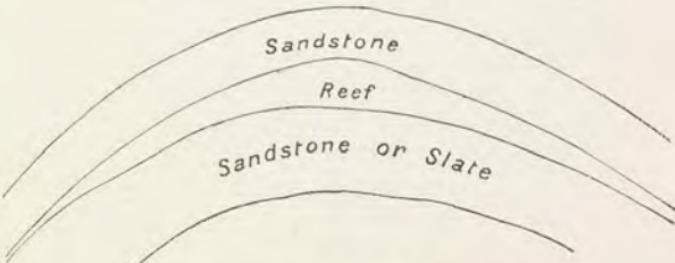


FIG. 38A.—EXAMPLE OF SADDLE REEF FORMATION.

*New South Wales*.—In lodes through Silurian, Devonian, and Carboniferous rocks. In lodes at junction of diorite and serpentine; also through diabasic rocks. In sandstone, conglomerates, &c.

*Queensland*.—In quartz veins, mostly through metamorphic rocks, though sometimes through granite and syenite, and in alluvial deposits derived from these. At Mount Morgan the auriferous deposit has probably been the result of a geyser, the gold being contained in a siliceous sinter. In some parts the matrix is aluminous; in others, ironstone predominates. Also in lodes through diorite.

*West Australia*.—In ordinary lodes or compound lodes in diorite (notably in Coolgardie district), in diabase, in diorite schist, micaceous schist, chlorite schist, hornblende schist, talcose schist, granite, slate, shale, kaolin, serpentine, &c. In some places the lodes are interbedded with schists. The country rock of the Black Flag district is hard felsite, porphyry, &c.

At the Great Boulder the gold-bearing rock contains a mixture of quartzose ironstone, felspathic material, &c. The veins run through hornblendic and diorite schist.

Gold is found at Hannan's in diabase dykes, &c. Rich tellurides are frequently found in depth.

At Nullagine, in the north-west, there are gold-bearing conglomerates (also diamondiferous) somewhat similar to the "basket" of the Transvaal.

Of some of the minerals in which gold occurs unexpectedly may be mentioned jasper, graphite, quartz crystals, chrysoprase. It is also found in sinter, felspar-porphyr, &c., and also disseminated in schist, granite, &c.

*New Zealand*.—In beds of rivers, in valley bottoms, and on flat land as a deposit, sometimes in a conglomerate formation, along the seashore mixed with magnetic iron, in glacial drifts, &c. In quartz veins through metamorphic rocks, also through andesite.

*New Guinea*.—In auriferous black sand. In a deposit of decomposed slate, quartz rock, and conglomerate, above which are leaf-bearing clays.

## ASIA.

*India*.—Gold is found in a very great many different localities, and both in veins and alluvial deposits. In the Wynnaad are gold-bearing reefs running through granitic and metamorphic rocks.

*Ceylon*.—In veins through chloritic and micaceous rocks.

## SOUTH AFRICA.

*Lydenberg*.—In fissure veins ; in seams of quartz and crystalline conglomerate between beds of shales, sandstones, and schists.

*De Kaap Valley*.—In fissure veins ; in nearly vertical beds of quartz and quartzite (sometimes carrying sulphides) between layers of schists and shales.

*Witwatersrand*.—Chiefly in quartz conglomerate.

Quartzite separates the reefs in the main reef series. The conglomerate ("basket") consists of whitish or greyish quartz pebbles cemented together by iron pyrite matter in which is the gold ; sometimes the gold is met with as a film on the outside of the pebbles. In some of the other reefs the quartz pebbles are of various colours. As depth is gained, instead of metallic oxides, sulphides are found. Some of the gold is found as crystals.

The "basket" conglomerates are newer than the schists and shales with compact quartzite (some of which, however, are gold-bearing) occurring in many districts. In West Africa there are formations like those in the Transvaal.

Elsewhere are reefs in granite, gneiss, slates, &c.

The Main Reef series crops out at Johannesburg. Half a mile or so south is the Bird Reef series. Another mile further south is the Kimberley Reef series. Two miles beyond is the Elsburg series (seven reefs). All these are stratified with quartzites.

Beyond there are  $1\frac{1}{2}$  miles of basaltic rock, then quartzites with the Black Reef, which is nearly flat, while the reefs of the former series dip from  $40^\circ$  to  $80^\circ$  South, the strike being nearly E. and W.

At the outcrops the conglomerate pebbles are not so

compactly cemented together as those deeper down, and have a reddish brown colour on the outside and in the cementing material.

In depth the conglomerate is usually greyish, and in the hard siliceous cement small crystals of iron pyrites are scattered about.

*Manica and Mashonaland.*—Quartz lodes in diorite, schists, granite, &c. Gold is sometimes found scattered about in diorite.

#### AMERICA.

*Canada.*—In alluvial deposits above talcose and other schists; in lodes through granite, schists. In fahl-bands, &c.

In Ontario the gold-bearing veins are usually in Huronian (pre-Cambrian) country rock. In some places the gold is found disseminated through schist, porphyry, &c.

*Nova Scotia.*—In quartz lodes through serpentine; in saddle reefs, not unlike those in Australia, &c.

*British Columbia.*—Lodes in diorite, between dykes and diorite, &c.

*California.*—In extensive alluvial deposits at the base of

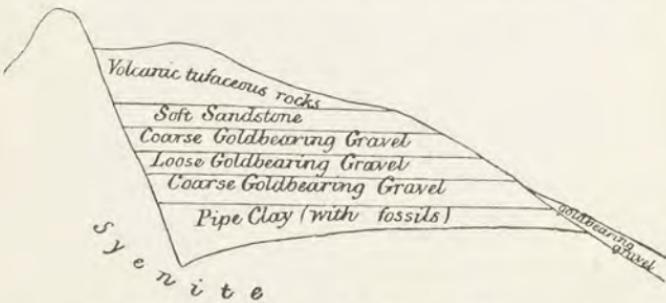


FIG. 39.—SECTION OF SPANISH PEAK DEPOSITS (CALIFORNIA).

the Sierra Nevada, in the beds of modern and ancient streams, in magnetic iron sand, in lodes through granite,

gneissic and other metamorphic rocks, in seam diggings of decomposed bed-rock with irregular seams of auriferous quartz. (Fig. 1.) In Placer county the lodes running E. and W., also N. and S., traverse syenite, also metamorphic slate. In Nevada county certain lodes run N.W., and also N.E., the country rock being granite, greenstone, and slate; generally speaking, the lodes run through metamorphic schists, or greenstone, alternating with belts of syenite.

In the Rocky Mountain regions (Colorado, Montana, Dakota, New Mexico, &c.) placers and auriferous lodes are plentiful. As a rule the lodes run through granitic rocks and metamorphic schists and slates, gneiss and quartzite, the gold being associated with iron pyrites, galena, blende, silver ore, &c. So, too, elsewhere in North America. Gold

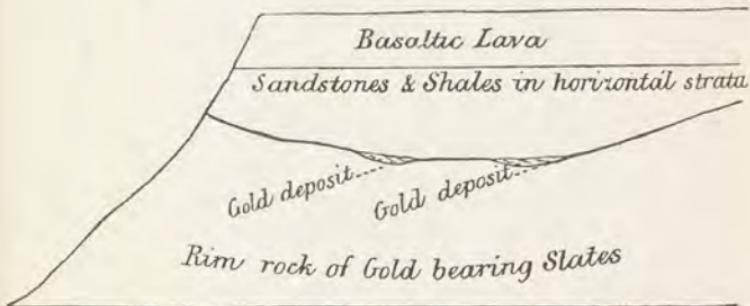


FIG. 40.—SECTION OF A PART OF TABLE MOUNTAIN (CALIFORNIA).

is sometimes found as a telluride (in Colorado, &c.), at Boulder in lodes through micaceous schists, gneissic granite, &c., between granite and porphyry. Also in West Australia, New Zealand, Transylvania, Hungary, &c.

At Cripple Creek, Colorado, some lodes run through andesite. At Telluride, Colorado, some gold and silver-bearing veins are in rhyolite, augite-andesite, andesite breccia, &c.

At Silver Cliff, Colorado (Bassick Mine), zones of various sulphides surround pieces of country rock, and carry silver and gold. Tellurides, too, occur.

In Utah, in one district, the precious metal is associated with cinnabar in a formation through limestone.

In British Guiana, in the neighbourhood of some of the alluvial diggings, the country rocks are chiefly granitic, syenitic and metamorphic. Eruptive dykes are plentiful.

As mentioned in the introduction to this book, the prospector should not necessarily confine his explorations to any particular district in an auriferous country. For instance, in Western Australia there must be large tracts of land which merit a systematic examination, notwithstanding that at the present time there are gold-bearing areas in the north (Kimberley), in the north-east (Pilbara and Ashburton), in the east (Murchison), and in the south (Yilgarn, Coolgardie, and Dundas).

So, too, British Columbia offers a large field for prospecting; also many yet unexplored parts of Africa south of the equator. The Rand "banket" deposit, so especially rich in the precious metals, is known to be of very great extent, and other valuable conglomerates may yet be discovered in other regions, though perhaps not noticeably continuous with these. When once the real origin of the gold—sometimes found in crystals—in the "banket" is really known, attention may be perhaps paid to various localities in various parts of the world where like natural processes may have taken place in depositing the gold. The very ocean contains—how uniformly is difficult to assert—gold in solution; and if it has done so in the past ages, one need not be astonished to know that in certain places where, for instance, the salt water has been evaporated, or where nature's precipitants—not, of necessity, like those employed in the laboratory—have thrown down the metal from its solution, gold fields, yet to be worked, may exist.

Suffice it to remark, gold seems to be very much distributed throughout the world; and consequently the prospector should keep his eyes open wherever he goes and get rid of the notion that good specimens of gold in lode, quartz, or alluvial deposits are the only desiderata so far as he is concerned in his searchings.

In many mines, where labour, &c., is cheap, and the quantity of ore great, a few pennyweights of gold to the ton will pay to extract, and even in a mine where the ore yields averagely nearly  $1\frac{1}{2}$  oz. per ton, the amount of gold in bulk is very small compared to that of quartz (say equal to 5 sovereigns in 14 or 15 cubic feet of quartz). Thus it really matters little whether the specks of gold are visible to the naked eye or distributed in a very finely divided state throughout the mass, so long as it is recoverable by some of the many methods now in use, and of course likely to be improved upon in the future.

**IRON.**

When heated before the blowpipe some of the ores are infusible, while most become, if not naturally so, attractable by the magnet. When the test is not destroyed by the presence of other metals, iron in a mineral when heated with borax on a platinum wire in the inner flame produces a bottle-green glass; in the outer, a dark red, when hot; a light red, when cold.

**Iron Pyrites (*mundic*).**

*Crystallization*—usually cubical; also octahedral, &c.

*Lustre*—frequently bright metallic.

*Colour*—yellow of different shades.

*Streak*—brownish black.

H.—6 to 6·5; S.G.—4·5 to 5.

*Composition*—about half iron and half sulphur.

Strikes fire with steel, and has slightly peculiar smell when broken. If heated before B.F., sulphur fumes are given off, and eventually a globule of metal, attractable by the magnet, is obtained. The powder of iron pyrites is very slowly soluble in nitric acid. This ore carries gold in either a small or great quantity, and is generally to be found in gold-bearing and other lodes, oxide of iron, colouring the quartz brownish, representing at the surface the decomposed iron pyrites such as exists in the vein deeper down.

The mineral is often mistaken for copper pyrites and sometimes for gold, but its being too hard to be cut by a knife is a distinguishing test. Iron pyrites is not employed for the extraction of iron; it is the chief mineral, however, from which sulphuric acid is obtained. In Spain are very rich deposits from which most of the ore brought to England is mined, although the Coal measures of this country are productive.

**Magnetic Pyrites.**

*Crystallization*—hexagonal prisms, &c.

*Colour*—between copper red and yellow, inclining to bronze.

*Streak*—greyish black.

H.—3·5; S.G.—4·4 to 4·6.

*Composition*—about 60 per cent. iron, the rest sulphur.

In the outer B.F. on charcoal, a red oxide of iron globule is formed; in the inner flame, fuses and yields a black magnetic globule having a yellowish fracture. It is not so hard as iron pyrites, and is slightly attracted by the magnet.

**Arsenical Pyrites** (*mispickel*: often called mundic by miners in Cornwall and Devonshire).

*Crystallization*—rhombic prisms modified on the angles, &c.

*Colour*—silver white.

*Streak*—greyish black.

*Lustre*—shining.

H.—5·5 to 6; S.G.—6·3.

*Composition*—about 35 per cent. iron, the rest arsenic and sulphur; cobalt sometimes occurs in the ore.

Before B.F. a magnetic globule is obtained, and a smell of garlic noticed. Strikes fire with steel, and a decided odour of garlic noticed. Heated in a tube a sublimate is obtained.

**Specular Iron** (*haematite*).

*Crystallization*—rhombohedral; some crystals are thin hexagonal tables with oblique edges.

*Colour*—dark steel grey in some varieties, but red in some earthy ones.

*Streak*—powder invariably dark cherry red.

H.—5·5; S.G.—4·5 to 5·3.

*Composition*—70 per cent. iron, the rest oxygen.

Infusible before B.F., but with borax gives a yellow glass in the outer flame, a green glass in the inner flame.

Varieties of this ore are:

Specular iron—of a metallic lustre.

Red haematite—an opaque mineral, not of a metallic lustre, brownish or red in colour. Has a radiated structure.

Red ochre and red chalk—soft and earthy, generally containing a quantity of clay.

Jaspery clay iron—clay ironstone, &c.

Micaceous iron ore (a scaly variety) is used as the basis for a certain kind of paint.

#### **Magnetic Iron Ore (*loadstone*).**

*Colour*—dark iron grey with metallic lustre.

*Streak*—black.

*Structure*—brittle.

H.—5·5 to 6·5; S.G.—5 to 5·1.

*Composition per cent.*—peroxide of iron, 69; protoxide of iron, 31.

Infusible before B.F. Yields bottle-green glass when heated with borax in inner flame. If powdered, the iron can be separated from impurities by the magnet. Not acted on by nitric acid; but when powdered is soluble in hydrochloric acid. Masses of specular iron ore and magnetic iron may sometimes be mistaken for one another; the difference of streaks easily distinguishes them. This ore is the most important in the north of Europe.

#### **Brown Iron Ore (*limonite*).**

Sometimes earthy. Massive, with botryoidal and smooth surface, &c.

*Structure*—fibrous.

*Colour*—brownish yellow and coffee colour.

*Streak*—yellowish.

*Lustre*—dull or submetallic.

H.—5 to 5·5; S.G.—3·6 to 4.

*Composition*—85 per cent. of iron peroxide, of which seven-tenths is pure iron.

Before B.F. blackens and becomes magnetic. Gives bottle-green glass in the inner flame when heated with borax.

#### Varieties:—

Brown haematite—Botryoidal, stalactitic, &c.

Yellow and brown ochre—Earthy.

Bog iron ore—Of a loose, friable texture. Found as a black or brownish earth in low swampy ground.

Brown or yellow ironstone—Hard and compact.

**Franklinite (an American ore).**

*Colour*—dark black.

*Streak*—dark brown.

*Structure*—brittle.

*Composition*—66 per cent. peroxide of iron, manganese, and zinc.

In appearance is something like magnetic iron, but less metallic.

**Copperas (green vitriol).**

*Colour*—greenish white.

*Lustre*—glassy and subtransparent.

*Structure*—brittle.

Contains 25 per cent. of oxide of iron, also sulphur and water.

It is formed by the decomposition of iron pyrites.

**Vivianite.**

*Crystallization*—oblique prisms.

*Lustre*—pearly or glassy.

*Colour*—deep blue to green.

*Streak*—blue.

H.—1·5 to 2; S.G.—2·6.

*Composition*—42 per cent. protoxide of iron, phosphoric acid, and water.

Becomes opaque before the blowpipe.

**Spathic Iron (iron spar, carbonate of iron).**

Sometimes massive, with a crystalline structure

*Crystallization*—hexagonal, rhombohedral &c.

*Lustre*—glassy or pearly.

*Colour*—yellowish grey to rust colour; becomes brownish red to black on exposure.

*Streak*—uncoloured.

H.—3 to 4·5; S.G.—3·7.

*Composition*—62 per cent. of protoxide of iron, carbonic acid, &c.

Before B.F. it blackens and becomes magnetic. Colours borax green. Dissolves in nitric acid, but, though a carbonate, does not effervesce much, unless in a powdered state. Heated in a closed tube, often decrepitates, and turns black and magnetic.

Clay ironstone of the Black Band seam is an impure variety.

The oxides and carbonates of iron are the principal ores, and their gangues are calcareous, argillaceous, siliceous, or bituminous, their value depending in a certain degree on the associated minerals. Thus:—In spathic ores, 5 to 15 per cent. of manganese or carbonaceous matter in a clay stone is an advantage; whereas some iron ores are decreased in worth by being associated with iron pyrites, &c.

Magnetic iron ore occurs in granite, gneiss, schist rocks, clay slate, and limestone.

Remarkable deposits of red haematite occur in Carboniferous, Cambrian, Silurian, and Devonian rocks. In Cumberland, North Lancashire, and Wales, veins run north and south in mountain limestone. Brown iron ore deposits occur in Carboniferous Limestone and Lower Coal measures in several places in England and Wales, also in the Lias, Oolite, and Lower Greensand of some places. In Spain brown haematite is found in a cretaceous formation. Spathic ores occur in carboniferous rocks, as well as in Devonian and older rocks. Clay ironstone is found in shales and clays of the Coal measures, also in Lias formation.

The Titaniferous iron ore, sometimes massive, but usually in the form of dark black sand washed down from the rocks in the country around, is very plentiful in some parts of North America, New Zealand, &c., and is often associated with gold, gems, heavy metallic compounds, &c. Unfortunately the ore is rather refractory.

It can be distinguished from specular iron (for which it might be mistaken) by its black streak.

#### Lead.

Lead compounds, if heated with carbonate of soda on charcoal before the blowpipe flame, yield malleable metal, and also a yellow oxide of lead incrustation.

If dissolved in nitric acid, the white sulphate of lead may be thrown down as a precipitate by adding sulphuric acid; or as chloride of lead by adding hydrochloric acid.

As, however, other chlorides might be formed at the same time, the precipitate should have ammonia added to it, when, if chloride of lead, it is unaltered.

**Galena (the principal ore of lead).**

*Crystallization*—cubical and cleavable in cubes, also octahedral.

*Lustre*—shining metallic; the surface may be dull, but the fracture is brilliant.

*Colour*—lead grey.

*Streak*—lead grey.

H.—2·5; S.G.—7·5.

*Composition*—when pure, 86·6 per cent. lead, the rest sulphur.

Unless heated carefully in the B.F. it is apt to decrepitate, but eventually yields a globule of lead. Can be decomposed by nitric acid. Galena can be distinguished from silver and other ores by blowpipe and chemical tests as well as by its characteristic cubical cleavage. The ore usually contains a perceptible amount of silver, and its presence may be observed by dissolving the ore in nitric acid and dipping a piece of bright copper into the solution, when a silver film will be formed. A galena ore should always be carefully assayed for silver, as sometimes it is very rich. It is an erroneous notion that fine-grained galena is more argentiferous than a coarse-grained one, though it might be in a particular district. Galena is frequently found in gold-bearing lodes.

**Carbonate of Lead (white lead ore).**

Often found near surface of a galena lode.

Compact, earthy, or fibrous masses.

*Crystallization*—prismatic, &c.

*Structure*—brittle.

*Lustre*—glassy or adamantine; is transparent or translucent, when pure.

*Colour*—white or greyish (sometimes with a bluish tinge) and often discoloured brown.

*Streak*—colourless.

H.—3 to 3·5; S.G.—6·5.

*Composition*—75 per cent. of lead, the rest carbonic acid, &c.

Before B.F. a lead bead is obtained.

If dissolved in nitric acid, and a piece of clean zinc be dipped in the solution, brilliant lead laminae will be precipitated on the zinc. Effervesces in acids. Red oxide is sometimes found on surface of lead ores, notably at Leadville, Colorado, on the carbonates. Specimens of a carbonate should always be examined for fragments of chloride of silver or chlorobromide of silver.

#### Pyromorphite.

*Colour*—greenish, sometimes bright grass green, the hexagonal crystals having a greasy lustre, also yellowish, brownish, and sometimes dull violet.

*Streak*—whitish or yellowish.

*Lustre*—more or less resinous; generally translucent. H.—3·5 to 4; S.G.—6·5 to 7.

Contains 78 per cent. of lead, as well as phosphorus, &c. Heated on charcoal before the B.F., a globule is formed which crystallizes on cooling, while a yellow oxide of lead incrustation is seen on the charcoal.

With carbonate of soda in R.F. yields a lead bead. Is soluble in nitric acid.

#### Chromate of Lead.

Is a yellowish mineral containing protoxide of lead and chromic acid. It blackens before the blowpipe and leaves shining globules of lead in the slag. Produces a yellow solution in nitric acid.

#### Sulphate of Lead.

A white, grey, greenish, or bluish, translucent or opaque mineral, with an adamantine lustre. Contains protoxide of lead and sulphuric acid. Rather like carbonate of lead, but is softer and does not effervesce in an acid.

Galena (generally mixed with other metals) is the usual

and most productive ore of lead, and is very frequently extremely rich in silver. It is found in rock formations of various ages in lodes, pockets, flats, &c.

The carboniferous or mountain limestones of England yield most of the lead ore, while it is also worked in the "killas" of Cornwall, a Devonian formation.

It also occurs in Great Britain and other countries in the Lower Silurian rocks, in granites, gneiss, &c.

The carbonate of lead deposits of Leadville, Colorado, best known for being richly argentiferous, occur between blue limestone and porphyry (Fig. 41).

Galena is generally associated with quartz, carbonate of lime spar, fluor-spar, sometimes barytes, copper and iron pyrites, &c. (For the assay of Galena, see Chap. IX.)

If powdered galena be heated in an iron spoon, lead can be obtained. The heat should be gradually raised at first till the pieces cease to decrepitate. After this a red heat will suffice.

The following is a simple method of obtaining lead bullion (though not the proper amount) from an ore, and may be of use to the prospector. Erect a square furnace of rough stones. Place rough logs of wood at the bottom, above this split wood, then broken-up ore, and then wood. The fire should be lighted at the entrance, and the lead allowed to run out into a basin.

#### MANGANESE.

The principal ore is the black oxide (grey manganese or pyrolusite).

Found compact or granular; the black powder in the cavities will soil the fingers. Small brilliant crystals, like cut steel, are sometimes met with; also botryoidal masses with a fibrous structure.

*Lustre*—submetallic.

*Colour and streak*—black.

H.—2 to 2·5; S.G.—4·8 to 5.

*Composition*—63·3 per cent. manganese, the remainder oxygen.

Effervesces briskly with borax before the B.F.

The oxide of manganese, when heated with borax on a platinum wire, colours the bead violet to black when hot, reddish violet when cold, in the O.F.; colourless when hot, colourless to rose colour when cold, in the R.F. If a mineral together with carbonate of soda be fused, a greenish glass will suggest the presence of manganese.

Wad (bog manganese) is an earthy or compact variety of manganeseite, a mineral which differs from the black oxide in containing 10 per cent of water. *Psilomene* is a hydrous oxide of manganese which contains baryta and other substances. When heated with borax produces a violent effervescence. Oxides dissolve in hydrochloric, also in a boiling solution of citric acid.

Manganese spar (of a reddish colour) consists of manganese protoxide, silica, &c.

Manganese deposits occur in different parts of the world and seem to have been derived from the metal originally scattered about in rocks of the ancient formations.

## MERCURY.

If heated in a glass tube together with carbonate of soda, mercury compounds yield a sublimate of mercury on the cold part of the tube.

### Native Mercury.

Is sometimes found as fluid globules of a tin-white colour. S.G.—13·6. Is volatile before the B.F., and easily dissolves in nitric acid.

### Cinnabar (*sulphide of mercury*).

This is the ore from which commercial mercury is obtained. Sometimes found massive, with a granular structure, sometimes in a crystallized form, the crystals being brilliant, transparent, and of a beautiful carmine colour.

*Colour*—generally red, sometimes bright red; also brown, brownish black, &c.

*Streak*—red.

*Lustre*—unmetallic.

*Structure*—sectile.

H.—2 to 2·5; S.G.—6 to 8.

Contains 86 per cent. of mercury, the rest sulphur.

Is volatile before the B.F. Soluble in aqua regia (4 hydrochloric acid and 1 nitric acid), but not in either hydrochloric or nitric acid. A piece of clean copper placed in the solution will be coated with a film of mercury.

If the powdered ore be placed together with quicklime in an iron pan and gently heated, a globule of mercury will be found at the bottom of the pan.

If the powdered ore be placed in a glass vessel capable of standing heat, such as a thin oil flask, and exposed to a strong flame, the mercury will form a sublimate on the upper and cool part of the vessel.

If heated in a tube closed at one end, globules of mercury condense on the cool portion. Near the test piece a black (red on being rubbed) sublimate is formed.

By placing powdered ore in the mouth of a tobacco-pipe, closing the mouth with clay, and exposing the bowl to a fair heat, the mercury may be collected on a cool surface, held so that the fumes given off may be condensed.

A gold coin or a piece of clean copper placed in the fumes will soon have a deposit of mercury on its surface.

#### **Chloride of Mercury (*horn quicksilver*).**

Is crystalline and granular, of a dirty white or ash grey colour, and a yellowish streak. Frequently associated with cinnabar.

H.—1 to 2; S.G.—6·48.

#### **Selinide of Mercury.**

Of a steel or lead grey colour and metallic lustre; occurs in Mexico.

The following are some of the places where cinnabar is found and its mode of occurrence:—

*California*—As deposits in cretaceous rocks, &c.

*Idria in Illyria*—Disseminated through bituminous schist, limestone, or grit.

*Spain*—In veins traversing a micaceous schist.

*Australia*—In veins through Devonian rocks, &c.

*Italy*—In small veins through mica slate.

*Mexico*—There is a mercury-producing vein in pitchstone porphyry.

*South America*—There is a mercury-bearing ore in strata of shales and sandstones, &c. In Utah is found associated with gold.

Generally speaking, mercury ores occur in both early and late geological formations. In New South Wales small rounded pieces of cinnabar have been found in a gold and gem-bearing alluvial.

#### MOLYBDENUM.

To test the presence of molybdenum in a mineral, heat it before B.F. on charcoal. A yellowish-white sublimate (crystallized near the test piece; yellow, hot; white, cold) is formed and a greenish blue flame. The sublimate becomes of an azure-blue colour in the R.F.

The principal ore is the sulphide, like graphite in appearance, but easily distinguished by testing.

H.—1·2 ; S.G.—4 to 5. Composition—nearly 59 per cent. molybdenum, the rest sulphur. Very frequently a yellowish oxide (ochre) accompanies the sulphide as an inerustation. It contains 66 per cent. molybdenum. Molybdate of lead, yellow, affords metallic lead before the blowpipe.

#### NICKEL.

To test the presence of nickel in a mineral, by means of the blowpipe, requires great care. If heated on charcoal, together with carbonate of soda in the inner flame, a grey metallic powder, attractable by the magnet, is formed. If heated with borax on platinum wire in the outer flame, a hyacinth red to violet brown glass results when hot, a yellowish or yellowish red when cold. In the reducing flame a grey bead is formed.

#### Kupfernickel (*Arsenical nickel*).

Generally massive, kidney-shaped, columnar, arborescent, &c.

*Crystallization*—hexagonal.

*Colour*—copper red (greyish or blackish when tarnished).

*Streak*—paler.

*Lustre*—metallic.

*Structure*—brittle.

H.—5 to 5·5; S.G.—7·3 to 7·7.

*Composition*—35 to 45 per cent. of nickel, the rest chiefly arsenic.

Often resembles native copper, but is harder. Soluble in aqua regia, and forms a green solution which becomes a violet blue by the addition of ammonia.

#### White Nickel (*nickel glance*).

*Crystallization*—cubical.

*Colour*—silver white or steel grey.

*Streak*—greyish black.

*Lustre*—metallic.

*Structure*—brittle.

H.—5·5 to 6; S.G.—6·4 to 6·7.

*Composition*—25 to 30 per cent. nickel, the rest arsenic.

Soluble in aqua regia.

#### Emerald Nickel (*a carbonate of nickel*).

Is of a bright green colour, and contains 28·6 per cent. of water.

In addition to the above may be mentioned the prolific hydrated silicate of nickel found in New Caledonia.

*Colour*—green, light or dark.

*Streak*—light green.

S.G.—2·2 to 2·86; H.—2·5.

Gives off water when heated. Fuses in borax before B.F., and gives the ordinary nickel bead. Is a silicate of nickel and magnesia, with iron, &c. Good specimens yield 12 per cent. nickel. Is found in lodes and pockets in serpentine rock. Matrix, cellular silica. Sometimes in a lode, the nickel is replaced by cobalt. Sometimes associated with chrome iron.

Excepting the New Caledonia ore, the principal ore is

kupfernickel. It occurs in many countries of Europe, in metamorphic, syenitic rocks, &c., and is generally associated with ores of cobalt, copper, silver, lead, &c. In Canada, a deposit of nickel ore occurs between magnesian limestone above and serpentine below.

On the surface of a nickel-bearing lode, some green stains may be noticed. A serpentine country is always worth prospecting for nickel, cobalt, and chromium minerals.

### PLATINUM.

This metal is found in the native state. Occurs in grains and masses.

*Colour*—whitish grey or dark grey.

*Streak*—whitish grey or dark grey.

*Lustre*—metallic.

H.—4 to 4.5; S.G.—16 to 21.

Iridium and osmium, &c., are usually mixed up with it. Wholly insoluble before the blowpipe flame. Can be dissolved in aqua regia (4 parts hydrochloric and 1 nitric acid), forming a yellowish solution, which becomes a bright red colour when protochloride of tin is added.

On account of the high specific gravity of platinum, it can be "panned out" from sand or gravel just the same as gold or other heavy metals.

If platinum be dissolved in aqua regia by boiling, and salammoniac be added to the filtered solution, a granular precipitate of a bright yellow or reddish yellow is formed. When this precipitate is heated, the metal, as "spongy platinum" powder, is obtained.

Platinum, though it is found in minute quantity in some metal-bearing veins, is usually met with as grains, generally flattened, in gold-bearing alluvial deposits, probably washed down from crystalline rocks.

**SILVER.**

Silver ores are easily fused before the blowpipe flame, either with or without carbonate of soda. The resulting globule of metal, of its characteristic white colour, can be readily hammered out or cut by a knife.

If the powdered mineral, supposed to contain silver, be dissolved in nitric acid and the solution be filtered or decanted, the presence of silver may be known by adding a solution of common table salt or of hydrochloric acid to the original solution. If silver be present, a white precipitate is thrown down. As chloride of lead or mercury might also be precipitated, let it be remembered that chloride of silver is soluble in ammonia, whereas chloride of lead is unchanged, and mercurous chloride blackened by it.

A very bright piece of copper, placed in the original solution, would be coated with metallic silver, if any existed. To test for copper, a bright knife-blade dipped into the solution would be coated with a copper film.

Sometimes, if a lump of silver-bearing ore be placed in a very hot fire, it will show white particles of the metal on the outside.

The silver metal soon tarnishes, when exposed to the action of sulphur; thus, if boiled along with the yolk of an egg, it will blacken.

**Native Silver.**

Found as wire silver, in thin sheets, in tree-like shapes, &c., and as octahedral crystals.

*Colour and Streak*—silver white. When found in veins is usually tarnished on the surface.

*Structure*—easily cut and hammered out.

H.—2·5 to 3; S.G.—10·1 to 11·1.

The silver usually contains gold and copper. Is recognised by the blowpipe and acids, as above mentioned. Native silver is often associated with iron rocks, native copper, &c.

**Brittle Silver Ore (*sulphide of silver and antimony*).**

Found massive, compact, in rhombic prism crystals, &c.

*Lustre*—metallic.

*Colour and Streak*—black or iron grey.

H.—2 to 2·5; S.G.—6·29.

*Composition*—When pure contains about 71 per cent. of silver, the rest antimony, &c.

With carbonate of soda before B.F. it decrepitates, but readily yields a silver lead. If the mineral be dissolved in nitric acid a piece of bright copper will be covered by a film of silver if placed in the solution. It is distinguished from silver glance by being brittle; whereas silver glance is soft and sectile, and chips can be cut off without crumbling.

#### **Silver Glance (*sulphide of silver*).**

A most important ore. Found massive, &c.

*Crystallization*—cubical, octahedral, &c.

*Fracture*—conchoidal or uneven.

*Colour*—blackish or lead grey (before exposure to the light has a bright metallic lustre).

*Streak*—same as colour, and shining.

*Structure*—soft and sectile.

H.—2 to 2·5; S.G.—7·1 to 7·4.

Contains 87 per cent. silver, the rest sulphur. Is usually associated with the sulphides of lead, copper, iron, zinc, antimony, arsenic, &c., also with nickel and cobalt ores.

Before B.F. with carbonate of soda yields globule of metal. Known in acid solution by usual tests. Is similar in appearance to some copper and lead ores, but distinguished before the B.F. and by its malleability. Is fusible at the temperature of an ordinary flame.

#### **Horn Silver (*chloride of silver*).**

A soft mineral found massive; also in crystals. Is nearly opaque, translucent on the edges, and has a waxy appearance.

*Fracture*—conchoidal.

*Colour*—greenish white, pearl grey, brownish, dirty green, &c., and on exposure, brownish or purplish, &c.

*Streak*—Shining and grey.

Can be cut like wax, the surface of the cut part being shiny.

Contains about 85 per cent. of silver, when pure. Not soluble in acids.

Fuses in a candle flame. Before B.F. readily yields metal. The surface of a plate of iron is silvered by it when moistened and rubbed. Occurs (often with carbonate of lead) in the upper parts of lodes. Silver bromide and iodide occasionally accompany the chloride. If a slice moistened be placed on a piece of zinc foil, the latter is soon stained black, and the chloride of silver partially reduced to metal on the surface against the foil. Forms a large portion of the South American "pacos" and "Colo-rados" ores.

#### Ruby Silver (*pyrargyrite*).

Massive, granular, or as prismatic crystals.

*Lustre*—adamantine and submetallic.

*Colour*—Sometimes black, reddish black, or brilliant cochineal colour.

*Streak*—lovely crimson red.

H.—2 to 2·5; S.G.—5·4 to 5·6.

Contains about 60 per cent. of silver, the rest arsenic, &c. Occurs with calcite, galena, &c. The dark red silver ore is a sulphide of silver and antimony; the light red contains arsenic in the place of antimony.

The ores of silver occur in veins traversing granitic and gneissic rocks, clay slate, mica schist, limestone, &c., and are usually associated with the ores of iron, copper, lead (galena being always argentiferous), zinc, &c.

At the rich mines of Leadville, Colorado, the silver is found in the carbonate of lead deposit lying between a blue limestone formation below and a white porphyry above (Fig. 41).

The famous Comstock lode, Nevada, consisting of quartz (here and there calcite and decomposed rocks), sulphides of various metals, silver ore as argentite, native silver, gold, &c., lies between syenite above and metamorphic slaty rock below. In Mexico deposits of silver-bearing ore are found

in limestone, also between slaty and porphyritic rocks, and traversing igneous and metamorphic formations. In Chili chloride of silver and native silver are found in stratified beds above granitic rocks, the richest belonging, it is supposed, to the Cretaceous period. In Peru are silver-bearing beds above porphyry, and with limestone at the sides. In Colorado and other Western States and Territories of Amer-

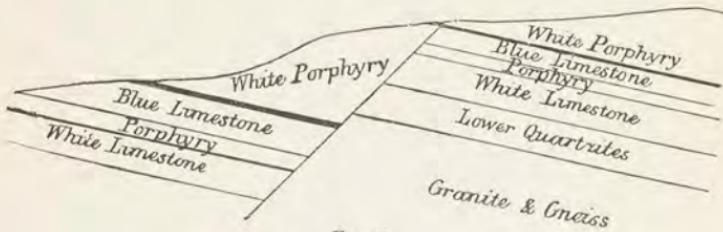


FIG. 41.

rica chloride of silver deposits occur in limestone, sandstone, &c. Andesite, trachyte, rhyolite, are some of the country rocks in which silver lodes occur in South America, while the usual silver-bearing fissure veins are very numerous.

The silver mines of the Barrier Range, N.S.W., are in metamorphic rocks, chiefly mica schist. Near the surface the ore contains carbonites of lead and copper, chloride of silver, &c., and, deeper down, sulphides, &c. Manganese is sometimes present.

Of late years, the value of silver having fallen so very much, many mines—notably those with galena (sulphide of lead) veins—have had to be closed ; and whatever they were in the past, and unless silver rises in value, must be ranked as of too low a grade to be profitable ; but this fact should not in any way make the prospector indifferent to any of the sulphide-bearing lodes. Whenever he notices an outcrop with traces of what would signify sulphides deeper in the lode, he should on no account rely on appearances, but should most assuredly have pieces of the rock properly assayed by an expert, because, for what he knows to the contrary, they may assay hundreds of ounces of silver

to the ton, and perhaps contain gold as well. Several mines in Western America from which silver and gold used to be worked, are still worked chiefly for the gold rather than for the silver and gold.

As suggested before, the remembrance of chloride of silver and carbonate of lead (carrying silver), both of which occur in many silver-bearing lode districts, should retain a corner in the thoughts of the prospector, who, whenever he has the opportunity, should thoroughly examine, and even experiment upon, pieces of these so very easily passed by minerals. Considering that a pure piece of chloride of silver, sometimes found in lumps in New South Wales, Chili, &c., contains 75 per cent. of the metal, it is easily understood how valuable a deposit of the same may prove. The carbonate of lead, too (with silver), most unlikely by outward appearance to suggest value, often contains much of the valuable metal.

**TIN.**

When a tin-bearing mineral is heated before the blowpipe with carbonate of soda or charcoal, white metallic tin is yielded. By dissolving this in hydrochloric acid and adding metallic zinc, the tin will be deposited in a spongy form. In the blowpipe assay, tin leaves a white deposit behind it, which cannot be driven off in either flame. If it be moistened with nitrate of cobalt solution, the deposit becomes bluish green, and this test distinguishes it from other metals.

The most important ore is—

**Cassiterite (*tin ore, oxide of tin, tinstone*).**

Massive and in grains.

*Crystallization*—in square prisms, octahedral, &c.

*Colour*—when pure, which is rarely the case, colourless and transparent, but usually brown, sometimes greyish or whitish, and occasionally reddish (as in Australia); transparent red crystals are rare.

Nearly opaque, and a resinous, submetallic lustre.

*Streak*—brownish.

H.—6 to 7; S.G. 6·5 to 7·1.

(N.B. Is much harder than zinc blende, for which it may, perchance, be mistaken. Is usually almost as hard as quartz, scratching glass, &c.)

*Contains*, when pure, 78 per cent. of tin.

Is infusible alone before the B.F., but with carbonate of soda metallic tin is yielded. Insoluble in acids, whereas zinc blende is easily soluble in hydrochloric acid.\*

**Stream Tin**

Is the ore found as rolled fragments of tinstone in the beds of streams or low-lying gravels.

**Wood Tin**

Is an uncryallized fibrous form of the mineral rather like dry wood, generally of a light brown colour, variegated with yellowish and dark concentric bands.

Tin ore sometimes resembles dark garnets, black zinc blende, &c.

\* As the S.G. is comparatively high, tinstone can be separated from minerals, such as iron and copper compounds, in a lode or deposit by "panning out." (Mispickel, however, has S.G. 6·3.)

**Bellmetal Ore (*sulphide of tin*).**

A rare ore, found massive and crystallized in cubes.

*Colour*—steel grey.

*Streak*—black.

*Structure*—brittle.

H.—4 ; S.G.—4·3 to 4·6.

*Composition*—27 per cent. tin; copper, iron, and sulphur.

Soluble in aqua regia.

Veins of tin ore traverse granite, gneiss, mica, slate, rhyolite, &c.

Tinstone is frequently scattered about country rock near the walls of a lode.

In Cornwall the lodes generally run east and west, and the average dip is  $70^{\circ}$ ; some also run across these. The ore is also found as a series of small veins in friable granite; also in masses, and as stream tin, as well as in veins between certain rocks and parallel to their beds. The true veins traverse granite and killas. In Queensland tin is obtained from a deposit, and also from lodes through granite rocks. In Tasmania from deposits and from lodes in a porphyritic rock. In New South Wales quartz veins carrying tin run through granite. The alluvial deposits of the Malay Archipelago are doubtless derived from veins in granite, and so are those in Burmah.

**URANIUM.**

Uranium in a mineral can be known by treatment with microcosmic salt before B.F., the cold beads being of a green colour (thus distinguishing it from iron); with borax in O.F. the cold bead is yellowish (thus distinguishing it from chromium). The principal ore is the oxide (often impure)—

*Pitchblende*—(one of the minerals containing the wonderful metal *Radium*).

*Colour*—usually blackish.

*Streak*—often blackish-brown.

H.—less or more than 5 ; S.G.—less or more than 6.

The powdered mineral boiled in nitric acid is dissolved; and, if ammonia is added to the solution, a yellow precipitate results. Pitchblende may contain more than 60 p.c. of uranium oxide.

The ochre, which frequently accompanies it, is yellowish. The phosphate, yellow or greenish.

### ZINC.

Minerals to be tested for zinc should be treated along with carbonate of soda on charcoal, before the blowpipe. The presence of the metal is known by the incrustation on the charcoal (very luminous when strongly heated) which is when hot, yellow; when cold, white. If the incrustation be moistened with nitrate of cobalt and heated, a fine green colour results. Before B.F., the metal is not obtained.

#### **Calamine**—(*carbonate of zinc*).

This is the most important ore. Massive, stalactitic, and not quite transparent.

*Colour*—when pure, pearly white; but owing to presence of iron oxide, &c., generally brownish, sometimes green.

*Streak*—whitish.

*Lustre*—pearly or glassy.

*Structure*—brittle.

H.—5; S.G.—3·3 to 3·5.

When pure, contains 52 per cent. of zinc; the rest, oxide of iron, carbonate of lime, and magnesia, &c.

Infusible alone before the blowpipe. Like other carbonates, effervesces in acid. Sometimes looks like calc spar.

#### **Zinc Blende** (*sulphide of zinc, commonly called Black Jack*).

Massive and fibrous; crystallizes in octahedrons and dodecahedrons.

*Colour*—when pure, yellow and transparent, but more usually, brownish red, garnet red, or blackish and translucent.

*Streak*—white to reddish brown.

*Lustre*—waxy.

H.—3·5 to 4; S.G.—4.

Some specimens become electric.

*Contains* nearly 67 per cent. zinc: the rest sulphur, &c.

Only fusible on the edges when heated alone on the blowpipe. Dissolves in nitric acid. If roasted in a glass tube, some of the sulphur is given off and a residue, zinc sulphate (white vitriol), is left. Occurs with iron and copper pyrites, silver ores, &c. Soluble in hydrochloric or citric acid.

#### **Silicate of Zinc (*zinc glance*).**

*Colour*—whitish, blue, brown, or green.

Not quite transparent.

*Streak*—whitish.

*Lustre*—pearly or glassy.

H.—4·5 to 5; S.G.—3·3 to 3·5.

*Contains* about 53 per cent. of zinc; the rest silica.

Before B.F. froths up and gives a phosphorescent light. Is fusible alone. With borax, yields a clear bead. If heated in sulphuric acid it dissolves, and the solution becomes gelatinous when cool: also in citric acid.

#### **Red Zinc Ore.**

Granular or massive.

*Clearage*—brittle slices, rather like mica.

*Colour*—bright red.

*Streak*—orange yellow.

*Lustre*—brilliant.

Not quite transparent.

H.—4 to 4·5; S.G.—5·4 to 5·6.

*Contains* about 80 per cent. zinc.

Infusible alone before the blowpipe. With borax, yields a transparent yellow glass. Sol. in nitric or boiling citric acid.

The principal ore, calamine, occurs in veins, beds, and pockets, usually in limestone of Devonian, Carboniferous, or Oolitic age. Zinc blende is found in the limestones of Great Britain and elsewhere. It is often associated with several metals in a lode. In Cornwall there is a saying, "Black Jack rides a good horse;" that is, where zinc blende is met with at the top of a lode, copper may probably be met with deeper down.

## CHAPTER VI.

### OTHER USEFUL MINERALS AND ORES.

Black lead.—Coal ; anthracite ; bituminous ; brown coal.—Bitumen, asphalt ; naphtha ; petroleum.—Gypsum.—Apatite.—Alum.—Borax —Common salt ; nitrate of soda ; phosphate of lime ; heavy spar ; fluor-spar ; carbonate of lime.—Precious stones and gems ; diamond.—Table of characteristics of various precious stones and gems.

#### GRAPHITE (*black lead*).

*Lustre*—metallic.

*Colour*—dark steel grey.

*Streak*—black and shining

H.—1·2 ; S.G.—2·1.

Is greasy to the touch. Soils paper, if rubbed on it. Contains about 90 per cent. carbon ; the rest, iron, lime, &c. Is infusible before the blowpipe and insoluble in acids. In Cumberland, England, blacklead-bearing strata are found in slate rocks interbedded with trappean rocks. In Ceylon, in the upper strata of Devonian formation. In the United States of America, gneissic rock. Graphite is used in the manufacture of lead pencils, crucibles, &c.

#### COAL.

True coal (not lignite and brown coal) is usually found in beds or seams divided from one another by beds of shale, sandstone, grit, and clay, in the Coal measures belonging to the Carboniferous formation. The principal varieties are—

#### Anthracite.

A black, shining coal with sharp edges and conchoidal fracture. Streak, black. Does not soil the fingers. Is not easily lighted, but when alight gives out an intense

heat and very little smoke. Contains 90 to 95 per cent. of carbon.

#### Bituminous Coal.

Has a rather more waxy appearance than anthracite. Colour, black. Streak, blackish. S.G. not more than 1·5. Varieties : pitching or caking coal, splint coal, cannel coal (having a fine compact texture and conchoidal fracture, capable of receiving a good polish, sonorous when struck), cherry coal, jet (which is blacker than cannel coal but more brilliant in lustre), contains 73 to 90 per cent. of carbon.

#### Brown Coal or Lignite.

Colour, brown or blackish. Resinous lustre, sometimes dull. 50 to 90 per cent. carbon. Although in England and many other countries the carboniferous rocks contain large coal beds, the most useful mineral is met with in other formations, such as in New Zealand, where lignite is found of a recent as well as of the Jurassic or Cretaceous age. In various parts of North America the lignite-bearing strata belong to the Tertiary and Cretaceous period, &c. Coal occurs in oolitic rock in India and Virginia (North America).

#### BITUMEN.

Found both in the solid and fluid state. Is inflammable and has a peculiar odour.

Varieties :—

#### Asphalt.

A solid black or brownish mineral. Fracture, conchoidal with glassy lustre. H.—2. When pure, will float on water. In Trinidad there is a lake of it  $1\frac{1}{2}$  miles in circumference. It is solid near the edges, but boiling in the centre. Asphalt is found in the mountain limestone of Derbyshire and Shropshire, also in granite with quartz and fluor-spar in Cornwall.

#### Naphtha (*mineral oil*).

A fluid of a yellowish colour. Has a peculiar odour. Will float on water.

**Petroleum.**

A fluid, darker in colour than naphtha, sometimes black. Naphtha and petroleum contain 84 to 88 per cent. of carbon, the rest hydrogen. Asphalt, in addition to carbon and hydrogen, contains oxygen and a little nitrogen. In California it is found in strata belonging to the Tertiary age. In Colorado and other Western States, to the Cretaceous. In North Carolina, to the Triassic. In West Virginia, to the Coal measures. In Kentucky, it occurs near the base of Carboniferous Limestone. The West Pennsylvania oil strata belong to the Devonian age. The anticlinal ridges are said to be more favourable than the synclinal ones (see page 15).

**GYPSUM (alabaster).**

*Crystallization*—derived from a right rhomboidal prism.

*Colour*—white, grey, black, &c.

When pure, is clear and translucent, and of pearly lustre. In hardness most varieties can be scratched by the nail. S.G. 2.3. In composition is a sulphate of lime. Before B.F. becomes white and opaque, and is easily crumbled. All varieties, when heated and reduced to powder and mixed with water harden while drying. Gypsum (from which plaster of Paris is manufactured) occurs in recent Tertiary formations, and also in the various other formations as old as the Silurian. Is often associated with beds of rock salt as in Cheshire. Does not effervesce in acids: hence distinction between it and limestones and other carbonates.

**APATITE.**

A mineral very rich in phosphate of lime, and, after treatment, used for dressing the soil.

*Cleavage*—not well marked.

*Colour*—white, grey, greenish, &c.

*Streak*—white.

Is transparent to opaque.

H.—4.5 to 5; S.G.—2.9 to 3.3.

Some varieties are phosphorescent when heated. Before

B.F. fuses with difficulty on the edges. Dissolves slowly in nitric acid without effervescence. In Canada occurs extensively in limestone of the Laurentian age.

#### **ALUM** (*hydrated sulphate of potash and alumina*).

Is best known by its astringent, sweetish taste.

H.—2 to 2·5; S.G.—1·8.

Soluble in its own weight of boiling water.

Found in clay slates.

#### **BORAX** (*borate of soda*).

A white, opaque mineral of vitreous lustre, of conchoidal fracture, and of a sweetish alkaline taste. Before B.F. it swells up and becomes opaque, but melts afterwards to a transparent globule. Found as a lake deposit in Tuscany, Nepaul (India), and in various parts of America.

#### **NITRE** (*salt-petre*).

Is usually found native as an efflorescence on the soil. Is soluble in water. When thrown on live coal, causes vivid combustion. Composed of potash and nitric acid.

#### **COMMON SALT** (*chloride of sodium*).

*Colour*—white or greyish, sometimes rose red. Crackles when heated. *Taste*—saline.

Salt deposits are found in strata of various ages, and often associated with gypsum, magnesia, soda, &c.

#### **NITRATE OF SODA.**

Of various colours. Found as an efflorescence, also in a crust-like form. Soluble in water. When heated it deliquesces and burns with a yellow light. It may be distinguished from nitre by its deliquescing on exposure. Found in surface deposits, and under a conglomerate containing felspar, phosphates, &c. Associated with it are common salt, gypsum. Immense quantities are obtained from Chili.

**PHOSPHATE OF LIME.**

In addition to apatite, phosphates occur in many countries, such as England, France, Russia, in greensand and gault: the nodules frequently contain fossil shells, bones, &c. Also in tertiary formations and in limestone cavities.

**SULPHATE OF BARYTA (*Heavy spar*).**

Compact, granular, &c., and of a white colour. Slightly harder than rock salt and less than calc spar. S.G.—4·3—4·8. Composed of sulphuric acid and baryta (oxide of barium). Obtained from beds in the Cambro-Silurian formations, in carboniferous limestone, &c. When powdered it is used as a paint.

**ASBESTOS.**

Usually fibrous and silky in appearance, from which fireproof articles are manufactured, is a silicate of iron, lime, magnesia, &c. Certain serpentine minerals are fibrous, and have the appearance of asbestos.

**FLUOR-SPAR (*see Matrices*).**

Occurs as a matrix in veins through gneiss, clay-slate, also extensively obtained in carboniferous limestone. Used as a flux in the reduction of ores.

**CARBONATE OF LIME (*see Matrices*).**

Though occasionally as a matrix, carbonate of lime is very plentiful in many countries, and immense formations being common.

*Varieties*—chalk, oolite, compact limestone, granular limestone (marble), &c.

Carbonate of lime effervesces in acids and so can be distinguished from a silicate. Used as a flux in the reduction of metallic ores associated with silica, &c.

**PRECIOUS STONES.**

Most precious stones belong to such formations as granitic, gneissic, porphyritic rocks, &c., and are generally found in the *débris* of such ; and although certain diamond-bearing soils may be of a comparatively recent age, they are for all that made up of the constituents of the older rocks.

Corundum, sapphire, and ruby are found in gneiss, granite, mica slate, chlorite slate, dolomite, or granular limestone.

In Ceylon precious stones are searched for in the beds of rivers, also in a gravel deposit (generally ten or twenty feet below the surface). This deposit, called Nellan, consists of waterworn pebbles, together with pieces of granite, gneiss, &c. The gems occur in "pockets" and in groups. Rubies are also found in dolomite.

The Burmah rubies are found in a limestone deposit ; also in alluvial deposits (formed from disintegrated gneiss rock), in beds of rivers, in limestone rock, &c.

Veins through mica-schist and clay-slate, black limestone, cavities in granite have yielded emeralds : from porphyritic rocks precious opal has been obtained, also from sandstone ; also in a brown iron ore in Queensland.

Emeralds are found in various metamorphic rocks : clay slates, associated with calc spar, &c.\*

The turquoise of Persia is obtained from porphyritic trachyte : that of Silesia and Saxony from clay-slate : that of New Mexico in quartzite, sandstone, &c. In Arizona and Nevada, too, turquoises are found in clay slate.

Topazes are met with in talcose rocks, gneiss, granite, &c.

Diamonds are usually met with in alluvial soil, often on gold-diggings. In some Indian fields there is a diamond-bearing conglomerate made up of rounded stones cemented together, which lies under two layers, the top one of gravel, sand, and loam, the bottom of thick black clay and mud. Also found in flexible sandstone in America, India, &c. In N.W. of West Australia in a gold-bearing conglomerate.

In Brazil the most precious of all gems is obtained from a conglomerate of white quartz, pebbles, and light-coloured sand, sometimes with yellow and blue quartz and iron sand.

\* In Australia (with tin-stone, topaz, fluorspar), in kaolin or decomposed granite, in North Carolina (North America), in a vein of quartz and felspar, the country rock being mica-schist.

In South Africa the diamondiferous alluvial deposits consists chiefly of nodules of granite, basalt, sandstone, &c., and in it are garnets, jasper, agates, pebbles (streaked with a succession of parallel rings) whose specific gravity is the same as that of the diamond, &c.: so, too, in East Indies, &c. Diamonds are often associated in river diggings with topaz, garnet, zircon, spinel ruby, native gold, tinstone, &c.

At the Kimberley mine, which, more or less, represents others in the neighbourhood, the diamondiferous ground forms a "pipe" or "chimney," surrounded by formations totally different to the payable rock. The encasing material is made up of red sandy soil on the surface, underneath which is a layer of calcareous tufa, then yellow shale, then black shale, and below this, hard igneous rock. The diamond-bearing ground consists of "yellow ground" (really the decomposed "blue ground"), which is comparatively



USUAL FORMS OF DIAMONDS.

friable; and, deeper down, the "blue ground" (hydrous magnesian conglomerate), which needs blasting by dynamite. The "blue ground" is of a dark bluish to a greenish grey colour, and has a more or less greasy feel. With it are mixed portions of boulders of various kinds of rocks, such as serpentine, quartzite, mica-schist, chlorite-schist, gneiss, granite, &c. All this "blue ground" has evidently been subjected to heat. The gems are in the matter which binds together these rocks, not in the rocks themselves.\* A diamond-bearing "blue earth" formation occurs at Wajra Karur, India. Diamonds are also found in Russia, America, various parts of Australia, New Zealand, Borneo, &c. The method of detecting the diamonds is the same in principle everywhere. The big stones are thrown aside, and the smaller matter is washed and examined for diamonds.

\* Garnets abound in the "blue ground," also grains of black carbon, magnetite, kyanite (blue), and a light green mineral occur.

Diamonds, spinel ruby, or garnet are never found as six-sided prisms, and thus several commoner crystals can be distinguished from them ; nor are emeralds, sapphire, zircon found as cubes, octahedrons, or rhombic dodecahedrons. With the exception of diamond (which is pure carbon), pre-



FIG. 47.

ONE COMMON FORM OF GARNET.



FIGS. 48 and 49.

SOME FORMS OF SAPPHIRE.



cious stones may be divided into two classes—those which have alumina as the base, and those which have silica. Of the first are the sapphire, ruby, emerald, &c. ; of the second are the amethyst, opal, cat's-eye, agates, &c.

To estimate the value of an uncut diamond there is no



FIG. 49A.

ONE FORM OF CRYSTAL OF TOPAZ.

The crystals often have terminal facets.



FIG. 50.

ONE COMMON FORM OF BERYL.

The crystals often have bevelled terminal edges.

fixed rule, on account of the fluctuation of prices.

The hardness and lustre are the most reliable tests to detect this choicest of all gems. A diamond will scratch any mineral ; but in testing it care has to be taken that the angles be not broken, as, notwithstanding hardness, it is rather brittle.

Topaz may sometimes be distinguished from similarly-looking stones by its perfect cleavage; also when crystallized, by its striation being parallel to the long edges, whereas in rock crystal it is at right angles to them.

Beryl, aquamarine (light bluish or greenish), and emerald differ only in the colouring matter. Their cleavage is imperfect. The blue sapphire, *oriental* ruby, *oriental* amethyst, *oriental* emerald are pure alumina coloured by metallic oxides. Rock crystal is pure clear quartz. Amethyst (violet or purple), smoky quartz, cairngorm, rose quartz are transparent silica variously tinted—to which is due the peculiarity of its reflections.

In a mica-schist country garnets—opaque, translucent, or transparent—are sometimes very plentiful, and, if the waterholes and parts of the rocky stream beds, such as those under rocky ledges, be examined, they may frequently be gathered, even by the handful, and often quite collected together and apart from sand, &c. So, too, at the junction of a stream and a lake, small pinkish or brown patches of the little ones may be noticed at some little distance off. Though garnets, unless some of the larger and nicely-coloured ones, are of little or no value, their presence in the above places may be useful to the prospector, who certainly should examine the collections or patches for more valuable minerals, such as diamonds and other precious stones, as well as for minerals of greater specific gravity than that of the main constituents of the country rock, although the specific gravity of the garnet is only 3—4. Waterworn garnets are frequently nearly globular.

In the accompanying table certain peculiarities of precious stones, such as hardness and specific gravity, may be useful to the prospector; at the same time, especially when there is no apparent crystallization in a specimen to distinguish a certain precious stone from one which may be similar in appearance, yet, perhaps, of much less value, or, perhaps, more, is not always an easy matter, even though hardness may be a guiding test. To assist any one in doubt, and in many instances to settle the point, the dichroiscope (in shape a cylinder 2 inches long and 1 inch in diameter, and so easily carried about) is most useful, taking for granted that

some practice with the various kinds of translucent or transparent stones of various shades and colours has been acquired. A preliminary examination of a few sapphires and rubies, spinel rubies, garnets, topazes, tourmalines (green, brown, red), zircons of various colours, andalusite, water sapphire, coloured quartz (including amethyst), &c., will impart a confidence very much more than any tabulated results of dichroism, which depends much on the intensity or depth of colour in the stone.

Placing (by means of a tweezers) a translucent or trans-

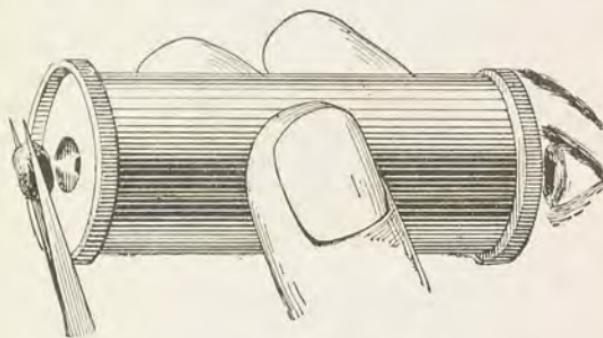


FIG. 51.—EXAMINING A GEM THROUGH THE DICHROISCOPE.

parent stone close to the one end of the instrument where the two square images are seen when the instrument, held skywards, is looked into, and turning it about in various directions, and at the same time turning the instrument round, the observer will notice whether the colour of the two squares is one and the same. If the stone is amorphous, such as glass, flint, obsidian, &c., or crystallizing according to the cubic system, such as diamond,\* spinel ruby, garnet, &c., the two squares will be of the same colour. In other cases the colour of one square will be of a different colour to that of the other when the coloured stone is examined in certain directions, though it may be the same in certain others.

Thus a true ruby, which affords two shades of pink, can

\* N.B.—Colourless gems of any kind do not show two distinct colours, and so the coloured diamond is here suggested.

be distinguished from a spinel ruby or garnet without dichroism, or from a pink tourmaline (rubellite), which gives two colours, but somewhat differently to those of ruby ; so, too, a sapphire, which gives a blue shade in one square and a light shade of colour without any shade of blue in the other (though sometimes in a deeply-coloured stone what might be considered as a greenish blue is noticed), can be distinguished from an amethyst, which affords two shades of purple, or from a blue spinel (which does not show any twin coloration), or from an iolite (or water sapphire), in which the coloration is of its own kind.

A tourmaline (very frequently associated with other gems,



FIG. 52.

When a transparent or semi-transparent stone is examined through the dichroscope, the colour of the square A is different, or of a different shade, to that of the square B when dichroism exists.

especially in Ceylon), either the green or brown, can be recognised directly (indeed, often without using the dichroscope) by the colour of the one square being quite dark compared to that of the other.

An emerald affords two distinct shades of green (one bluish) easily remembered (quite distinguishable from the dichroism of a green tourmaline); so a green garnet, which does not show twin coloration, cannot be mistaken for it.

With the dichroscope and two or three minerals, such as the sapphire, topaz, and rock crystal, to test for hardness, and a little practice—the more the better—and a slight knowledge of the crystallization of minerals, which, though frequently found water-worn, not uncommonly retain traces of the original crystal edges and faces, the prospector can examine his specimens with a very much easier mind than he would do without them.

Frequently neither the hardness of a gem stone nor its behaviour before the dichroiscope is sufficient to enable its identity to be reliably known. In such a case its specific gravity may settle the question ; but it must be confessed this requires a more accurate balance than the prospector may possess, and the advice of an expert may be necessary.

Of all the different transparent or translucent minerals there are only a few kinds of value, and so a knowledge of the dichroism of all these in different colours and different depths of colour should be acquired.

TABLE OF CHARACTERISTICS OF VARIOUS STONES  
AND GEMS.

Name of Precious Stone or Gem.	Colour, &c.	S.G.	$^{\circ}\text{H}.$	Crystallization.
Diamond	White or colourless in appearance like gum arabic, sometimes pink, yellow, mouse coloured, greenish, &c. Has adamantine lustre, and reflects light brilliantly. Boart is an impure variety, and carbonado is a black diamond. Not dichroic.	3·5	10	Octahedral, dodecahedral, faces sometimes curved (Figs. 31-35). Also in thin plates, twin crystals, &c.
Oriental Ruby	Reddish.	3·9	9	Hexagonal six-sided prisms or pyramids.
Oriental Topaz	Yellowish.	4·2	(thus harder than topaz,	The partially water-worn stones often show traces of crystallization.
Oriental Sapphire	Bluish.		and next to dia-	
Oriental Emerald	Greenish.		mond).	
Oriental Amethyst are all varieties of corundum.	Purple. Dichroic.			

\* When a stone to be tested for hardness is very small, it may be placed in a hole at the end of a stick and pressure applied during the test.

TABLE OF CHARACTERISTICS—*continued.*

Name of Precious Stone or Gem.	Colour, &c.	S.G.	*H	Crystallization.
Topaz . .	Usually yellowish, but also of other tints. Dichroic.	3·53	8	Rhombic. When crystallized, shows striation parallel to long sides of prism.
Spinel, including spinel ruby . .	Of various colours. No dichroism.	3·8	8	Cubic system, usually in octahedra.
Cat's Eye, a variety of chrysoberyl . .	Greenish grey and translucent. When polished displays beautiful internal reflections, like a cat's eye.	3 to 3·8	8·5 so harder than topaz.	Chrysoberyls when crystallized belong to right rhombic systems.
Emerald, a variety of beryl . .	Green. Aquamarine, is sometimes colourless, or with a bluish green tinge. Dichroic.	2·7	7·5 to 8	Hexagonal. Usually in long six-sided crystals, and often with striation parallel to the long edges.
Amethyst (coloured quartz)	Usually bluish or purple. Dichroic.	2·66	7·0	Hexagonal prism, often with pyramids.
Turquoise	Bluish green.	2·6 to 3	6	Reniform. Stalactitic. Incrustation.
Garnet (including carbuncle, almandine, pyrope, &c.)	Usually reddish or reddish brown; but of various colours, including green. Cinnamom stone, sometimes called jacinth, is yellow. Not dichroic.	3·5 to 4·2	6·5 to 7·8	Cubic system, usually in dodecahedra.
Iolite (water sapphire).	Demandotoid, green. Bluish; of a glassy appearance. Dichroic.	2·63	7·3	Trimetric.
Opal . .	Milk white, pearly grey, sometimes with yellow or red hues, &c.	2 to 2·3	5·5 to 6·5	Uncrystallized.

\* When a stone to be tested for hardness is very small, it may be placed in a hole at the end of a stick and pressure applied during the test.

Tourmaline (of various colours). H.—7·5. Very dichroic.

Peridot is a yellowish-green variety of olivine. Chrysolite, a yellow or greenish-yellow variety, is softer than quartz.

Zircon (including hyacinth and jargoon) is of various colours. S.G., 4·7, and thus the heaviest of precious stones. H.—7·5. Crystallization, tetragonal.

Moonstone, sunstone (with internal reflections), and adularia are varieties of felspar.

Lapis-lazuli is a nearly opaque, blue stone. (H.—5·2.)

Smoky quartz, cairngorm, false topaz, milky quartz, yellow or citron quartz, rose quartz, rock crystals, Bristol and Gibraltar diamonds, are varieties of quartz; so too are crocidolite, onyx, sardonyx, sard, bloodstone, jasper, agate, moss agate, or mocha stone, chrysoprase (of an apple-green colour), plasma (green), chalcedony, cornelian, avanturine (usually brownish or greenish, speckled with mica), heliotrope (spotted), firestone and quartz cat's eye, potato-stone, &c.

The crystallized varieties are usually of the form of hexagonal prisms capped by pyramids, and have approximately S.G.—2·65; H.—7.

Jade (generally slightly translucent and greenish, greenish white, milky white, &c., includes N.Z. greenstone. H.—6·5 to 7).

Alexandrite and oriental chrysolite are varieties of chrysoberyl.

There are many of the gems of comparatively little value that are in reality not always profitable for a person to pay much attention to the discovery of; that is, of course, unless the quantity of them is great, for the cost of polishing the same is an important factor in assigning a value to them. Many coloured transparent and translucent kinds of quartz, coloured by metallic oxides, fall under this category. But so easy is it to prospect a stream, say in a country of crystalline, plutonic, or metamorphic rocks, that a search for precious stones and gems of all kinds should be made much more than is usually the case. With regard to the precious varieties, it is well to bear in mind—for instance, when dealing with a heap of Ceylon gem stones—that the valuable specimens may be associated with all sorts of worthless specimens, all of which, though impure in quality, may really be sapphires, spinels, chrysoberyls, tourmalines, zircons, &c.

Though many are translucent rather than transparent, many dark in outward appearance, and all water-worn, more or less, and with surfaces not at all glass-like, and the majority not apparently transparent or translucent un-

less held up to the light, yet, here and there a good specimen may be found. For all that, a knowledge of the general appearance of such impure specimens is probably of as much importance as that of the good ones; for the prospector who comes across them has an encouragement in his search for valuable ones.

For some reason or other, diamonds and gold are often found in the same alluvial deposit, and so auriferous beds should be examined for the precious stone. The specific gravity of the diamond—higher than that of quartz or most pebbles—and that of gold are so very different, that it does not follow that, for instance in a stream bed, these two minerals are always found close together.

On page 89 it has been mentioned that diamonds are sometimes found in flexible sandstone; but if they are not discovered in a particular deposit of this sandstone, the presence of this formation in a district is a very good one for the prospector to know of, as the diamonds may still be found not very far off.

## CHAPTER VII.

### *COMPOSITION OF VARIOUS ROCKS.*

Granite.—Schists.—Gneiss.—Serpentine.—Basalt.—Pitchstone.—Obsidian.—Pumicestone.—Sandstones.—Limestones.—Dolomite.—Clays.—Nature of certain minerals in igneous and metamorphic rocks ; quartz; felspar; mica; talc; chlorite; hornblende; augite; olivine.—Matrices of veins; quartz; fluor-spar; calc-spar.

#### Granite.

Composed of quartz—white, black, grey, &c.—in rather irregular grains; mica, silvery white or metallic black (sometimes replaced by hornblende); potash felspar of a white, pink red, or yellowish colour, and crystallized. Contains 70 per cent. silica, with alumina, lime, magnesia, alkalies, oxide of iron, &c.; or 40 per cent. felspar, 30 to 40 per cent. quartz, 10 to 20 per cent. mica.

In foliated granite the grains are arranged in layers. In graphic granite the felspar is arranged in the quartz, or the quartz in the felspar, something like the letters in Oriental writing. Micaceous, quartzose, felspathic granite are varieties in which mica, quartz, felspar respectively predominate. Syenite is a variety of granite free from quartz, and chiefly composed of hornblende and potash felspar.

Porphyry is a compact felspathic rock of the nature of granite, having felspar crystals, mica, quartz, chlorite, &c., imbedded in it, which give it a speckled appearance.

#### Schists.\*

Mica schist consists of fine layers of quartz and mica; talc schist consists of fine layers of quartz and talc; chlorite

\* It is of the utmost importance for the prospector to become thoroughly acquainted with the appearance of these, as a schist country is always worth prospecting.

schist consists of fine layers of quartz and chlorite; hornblende schist consists of fine layers of quartz and hornblende.

*N.B.—In the so-called igneous rocks sometimes the minerals are distinctly crystallized, sometimes of a very compact appearance like broken porcelain.*

#### Gneiss.

Is made up of the same minerals as granite, only containing them in parallel layers.

#### Serpentine.

A greenish, grey, brown, &c., mineral, opaque and translucent. Breaks with a conchoidal fracture. H.—2·25 to 4; S.G.—2·5 to 2·6. Massive, foliated, or fibrous, and in appearance pearly, resinous, or waxy. Before B.F. whitens and gives off water. Contains 40 to 44 per cent. of magnesia, 40 per cent. silica.

#### Basalt.

When broken, of a black, bluish, greenish, greyish brown, &c., colour, though usually pale drab colour on the surface.

Thin sections under the microscope show lath-shaped crystals of felspar (not potash felspar) and augite, with sometimes olivine, &c.

#### Diorite.

A crystalline rock made up of felspar (lime felspar or lime-soda felspar) and hornblende or dark-coloured mica.

#### Andesite.

A volcanic rock with felspar (not potash-felspar) and augite or hornblende or mica occurring in a non-crystalline base. The crystals of felspar are frequently very glassy.

#### Obsidian.

A glass-like volcanic rock. It is often like dark bottle glass in appearance and transparency.

#### Pitchstone.

A volcanic rock much resembling obsidian in certain characteristics; but has not transparency, and is more pitch-like or resinous in appearance. Usually blackish; sometimes, however, reddish-brown, greenish, &c.

### Pumicestone.

A spongy, porous, volcanic rock, usually, though not always, greyish white or of some light colour. Floats on water, although the powder has a specific gravity above 2. Is very brittle. Before B.F. melts to a white enamel. In composition, nearly the same as obsidian. Hardly acted on by acids.

### Sandstones.

These rocks may always be recognised by their appearance, being made up of particles of sand cemented together. The grains (chiefly silica) are very hard. Do not effervesce in acid.

### Limestones.

Rocks chiefly composed of carbonate of lime, and consequently, like other carbonates, effervesce when a little hydrochloric acid is dropped on. Though infusible before the B.F., limestone glows with a very bright light. Varieties:—

*Chalk*—Soft, earthy, whitish and without lustre.

*Granular or compact limestone*.

*Oolite*, which consists of spherical grains, and in appearance like the roe of a fish. *Marly limestone, marble, calc spar, &c.*

### Dolomite.

A colourless, white, sometimes yellow, green, or pale red mineral, of a pearly, resinous, or vitreous-like appearance, is composed of carbonates of lime and magnesia. Is infusible before the B.F., but glows with a bright light. Though a carbonate, does not effervesce much in acid.

### Clays.

Contain usually about 40 to 50 per cent. silica, 30 alumina; water as well, sometimes, as iron, lime, potash, &c. When mixed with water clays may be kneaded by hand into various shapes. Usually, when in a dry state, very absorbent of water. Become hard when dried. Adhere to the tongue. Some clays give out a disagreeable earthy smell when breathed upon. Are generally infusible in a furnace.

Varieties :—

*Slate Clay*—Colour, greyish or greyish yellow. Fracture slaty. When ground and reduced to paste with water can be used as firebrick.

*Common Clay* (used for making bricks, tiles, and coarse pottery). *Loam*.

*Pipe Clay*—Colour, white or greyish white; feels greasy. Surface polishes when pressed by the finger.

*Potters' Clay*—More easily fusible. Of various colours; generally red, yellow, green, blue, &c., becoming red or yellow when burnt.

*Kaolin* (porcelain clay). The purest form of clay. Contains 40 to 42 per cent. alumina, 46 to 48 per cent. silica, and water. It is really decomposed felspathic rock. Kaolin is greasy to the touch, friable in the hand, and does not easily form into a paste with water. When heated, hardens and retains a white colour.

#### NATURE OF CERTAIN MINERALS

*Met with in various of the Igneous and Metamorphic Rocks.*

**Quartz** (see Matrices).

**Felspar.**

Colour usually white or red, occasionally grey, black, or green. Felspars scratch glass and can be scratched by quartz; but not well by a good knife. S.G.—2·5 to 2·7. Lustre commonly vitreous or pearly on the more perfect cleavage planes. Some varieties are iridescent or opalescent. With the exception of Labradorite, felspars are unacted on, or imperfectly so, by acids. Contains silicate of alumina with soda, potash, lime (sometimes two or more of these).

**Mica.**

A finely foliated mineral of pearly lustre. In colour sometimes white, grey, or black, and when exposed sometimes yellowish. Cleavage very perfect in one direction. Laminæ

very flexible. Usually occurs in thin scales ; sometimes in large plates. Harder than gypsum, not so hard as calc-spar. S.G.—2·5 to 3. Mostly fusible before B.F. Not readily acted on by hydrochloric acid. In its composition are silicates of alumina, with potash, magnesia, lime, iron, manganese, &c.

#### Talc.

A greenish, yellowish white, or sometimes colourless mineral of a pearly or resinous lustre. Is greasy to the touch ; soft ; yields to the finger-nail ; can be cut into laminae which bend but are not elastic. H.—1 ; S.G.—2·6 to 2·8. Before blowpipe is infusible, but whitens. Becomes red with nitrate of cobalt solution. Is not soluble in either hydrochloric or sulphuric acid. Composition per cent. : silica, 62 ; magnesia, 27 ; alumina, water, iron, &c.

#### Chlorite.

A dark green, generally foliated and scaly mineral. Streak, greenish grey. H.—1 to 1·5 ; S.G.—2·7 to 2·96. Soluble in hot sulphuric acid. Contains silicates of alumina and magnesia and water.

#### Hornblende.

There are many varieties of this mineral, mostly of a greenish black, and also whitish colour (those containing lime and magnesia, without iron, being light). Streak, white or slightly coloured. Lustre, vitreous. H.—4 to 6. S.G.—2·9 to 4. Scarcely acted on by hydrochloric or nitric acid. Unaltered when heated in a closed tube. More or less fusible before the B.F. Composed of silicates of lime, magnesia, also iron, alumina, &c.

#### Augite.

A dark green or blackish mineral, in composition like hornblende, of a pearly or vitreous lustre. Is met with in volcanic rocks.

#### Olivine.

A green or brownish transparent or translucent mineral

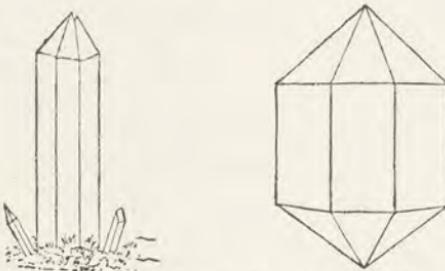
of a vitreous lustre, found imbedded in lava or basalt. Is harder than felspar, and sometimes equals quartz. S.G.—3·3 to 3·5. Dissolves in sulphuric acid, less readily in hydrochloric acid; the silica gelatinizes. Consists of silica, magnesia, iron, and oxygen.

#### MATRICES OF VEINS.

The principal ones are :—

##### Quartz.

Of nearly every colour, generally white or brownish, sometimes bluish, as in the Queensland gold districts, and



Figs. 53 and 54.—COMMON CRYSTALS OF QUARTZ.

of a dull glassy lustre. Scratches glass, &c., but cannot be scratched by a file or knife. Is infusible alone before the

B.F., but with carbonate of soda it dissolves to a glass. Is insoluble in acids, except hydrofluoric. If two pieces of quartz are rubbed together in the dark, a phosphorescent light is seen. When crystallized, is usually in six-sided prisms. H.—7; S.G.—2·6 to 2·7. At

Fig. 55. or near the surface of a lode the quartz has very often a honeycomb appearance, and stained brown, yellow, purple, or other colour, due to decomposed iron or copper pyrites, or other metallic substances, which may be expected to be found deeper down. Quartz is very nearly pure silica.



### Fluor-Spar.

Though by no means so common a matrix as quartz, it often forms or is mixed with the gangue of copper, lead, or silver-bearing lodes. Is usually purple, sometimes yellow, white, or green, and occasionally blue. If a piece be heated in a dark place, a phosphorescent light may be noticed. Fluor-spar might be mistaken for a precious stone; its softness, however, is a distinguishing feature.

Crystallizes most commonly in cubes, octahedra, &c. Crystals are transparent or translucent. H.—4; S.G.—3·14 to 3·18. Is brittle. When heated in a closed tube, decrepitates and phosphoresces.

Gives opaque beads when heated with borax and microsmic salt before B.F. If melted in a tube with microsmic salt it gives off vapour of hydrofluoric acid, which corrodes the glass.

If the powdered mineral be dissolved in sulphuric acid, the gaseous acid will corrode glass, and even siliceous stones. Blue John is a name given by Derbyshire miners to a blue fluor-spar. Composition: lime, 51; fluorine, 48.

### Calc-Spar (*carbonate of lime*).

Generally transparent or translucent. Crystallization



FIG. 56.



FIG. 57.



FIG. 58.

COMMON FORMS OF CALC SPAR.

rhombohedral, &c. Some common forms being as above. The faces are sometimes very brilliant. H.—3; S.G.—2·5 to 2·8. Is colourless, topaz, or honey yellow, grey rose, violet, &c.

Is infusible before the B.F., gives a very bright light, and is eventually reduced to a quicklime. It effervesces when acted on by an acid.

## CHAPTER VIII.

### *TESTING BY THE WET PROCESS.*

#### Systematic Plan of Procedure.

IN testing a mineral by the wet process, the method is to powder and thoroughly dissolve it in some liquid, usually an acid, or mixture of acids, and then to recognise the presence of some known metal or metals by the peculiarity of the precipitate produced, when a reagent has been added to the solution. If the mineral is likely to contain sulphur or arsenic or other such volatile substances in its composition (such as iron pyrites, copper pyrites, galena, &c.), a good plan is to powder and roast it in order to drive off the sulphur, and to leave the metallic portions in the form of oxide, and thus in a proper condition for easy examination. There are certain minerals, as graphite, cinnabar (the principal ore of mercury), some oxides, sulphates, chlorides, and a number of silicates, that are not soluble in acid. So as to simplify the testing of such as these, it is just as well to add to the powdered mineral about four times the weight of carbonate of soda, and to melt them in a crucible or other apparatus, so as to leave the metallic portion in a condition to be dissolved by hydrochloric acid ; but let it be remembered that the above methods are only suggested to render the tests more accurate than they would otherwise be.

Notwithstanding that the blowpipe tests are those chiefly to be depended upon, the following wet ones may be of use in determining the presence of some of the metallic bases in many of the common ores met with ; and the apparatus required is not very large, consisting of three acids (hydrochloric, nitric, sulphuric), potash, ammonia, protochloride of tin (if convenient) for the gold test, copper, and zinc, a few test tubes, porcelain capsules, &c.\* The principal objection to the wet process is the inconvenience of carrying

\* Also citric acid ; sulphate of iron for gold test, &c.

about powerful acids; at the same time, any chemist, if desired, will put them in strong and properly stopped bottles, which, when packed carefully in the compartments of a small box, will stand a good deal of knocking about.

The finely powdered mineral should be dissolved in hydrochloric acid or nitric acid (the latter being a substitute for roasting, and is the most suitable when the substance is a sulphide, or arsenide, or metallic alloy), and reagents added.

Place a little powdered ore in a test tube or other convenient apparatus (such as a porcelain dish), add a little water and pour in nitric acid; heat this over a spirit or other flame for a short time.

The clear solution is called the original solution, and (if there be any undissolved matter left as a residue at the bottom of the tube) should be filtered or decanted into another test tube.

To the clear solution add a little hydrochloric acid, when, if a precipitate is formed, it is,

#### **Chloride of Lead, Chloride of Silver, or Mercurous Chloride.**

Pour all the liquid off, and then shake this precipitate with ammonia and observe the results :—

If dissolved it is chloride of silver.

Confirmatory test for silver: add potash to the original solution and a brown precipitate would be produced.

If blackened it is mercurous chloride.

Confirmatory test for mercury: add potash to original solution and a black precipitate would be produced. Metallic copper (clean) placed in the solution would become silvery-looking.

If unchanged it is chloride of lead.

Confirmatory test for lead: add to original solution some sulphuric acid, and stir; a white precipitate, sulphate of lead, would be formed at the bottom of the tube.

Suppose, however, that no precipitate was formed on the addition of hydrochloric acid to the original solution. The presence of some of the metallic bases is best determined by passing sulphuretted hydrogen gas through the acid solu-

tion. If a precipitate is formed it may, if *black*, show the presence of mercury, lead, bismuth, platinum, tin, gold, and copper; if *yellow*, of tin, antimony, arsenic, or cadmium; but should no precipitate be formed, the addition of other reagents has to be made to determine the presence of iron, zinc, manganese, copper, nickel, and cobalt, &c.\*

The prospector will, however, find that usually his best plan is to take portions of the original solution, and to test them, one at a time, as follows:—

To separate portions of the original add reagents as in Table on the next page. The presence of antimony may be noted by adding a little hydrochloric acid to the original solution, and, introducing a piece of zinc—a sooty black precipitate will be the result.

To test a mineral for gold, the specimen must be thoroughly dissolved in aqua regia (4 parts hydrochloric and 1 nitric acid), then protochloride of tin added. The slightest trace of gold will cause the purple precipitate (called purple of cassius) to be formed; if a bright red solution results, there is platinum present. If, instead of the protochloride of tin, a solution of sulphate of iron (copperas) be added, the gold would be precipitated as a brown powder.

Though, generally, testing for a metal in a mineral is most satisfactorily performed by means of the blowpipe, there are cases in which there is great difficulty in obtaining proper results; for instance, when several metallic compounds are combined in the same specimen. Under such or other circumstances, individual tests, by means of the addition of reagents to the original solution, are most useful.

Again, the action of an acid on a mineral frequently enables the operator to determine whether the mineral is a silicate, a carbonate, &c.—if the former, sometimes by gelatinization; if the latter, by effervescence; and the evolution of nitrous acid vapours will suggest that copper, copper pyrites, or some metalliferous substance, not an oxide, may be present.

\* Analogous test by fusion: If, when a mineral be fused with hyposulphite of soda, the mass is black, it denotes the presence of bismuth, cobalt, copper, gold, iron, lead, mercury, nickel, platinum, silver, uranium; white, zinc; red, antimony; green, chromium or manganese; brown, tin or molybdenum.

REAGENTS TO BE ADDED TO THE ORIGINAL SOLUTION.

I.	II.	III.
DILUTE SULPHURIC ACID.	AMMONIA IN EXCESS.	POTASH IN EXCESS.
White precipitate shows the presence of lead.	Blue colour shows presence of copper or nickel. Copper may be known by introducing the point of a polished knife-blade into the solution mixed with hydrochloric acid in excess : a coating of copper is formed.	White precipitate shows presence of bismuth or mercury. By dissolving the precipitate with dilute hydrochloric acid, and introducing a piece of bright copper and boiling, the mercury, if present, will form a silvery coating on the copper.

Blue precipitate shows presence of cobalt.  
Light green , ,  
White precipitate becoming brown when shaken in the air , , manganese.  
Brown orange, which becomes brown on exposure to the air , , iron.  
White , , zinc.  
Yellow , , mercury.

## CHAPTER IX.

### ASSAY OF GOLD.

Various methods.—Fluxes, reagents, &c.—General treatment of ores.—Preparation of the sample.—Weighing, &c.—Assay ton.—To construct a simple button balance and to use it.—Dry assay for gold and silver.—Apparatus and procedure.—Fusion in a crucible.—Scorification.—Cupellation.—Indications of the presence of metals known from cupel stains.—To make cupels.—Dry assay for lead in galena, tin, antimony.—Wet assays for gold, silver, lead, copper, iron.—Roasting.—Mechanical assay of ores.

To determine the amount of metal in an ore, there are two kinds of assay adopted.

The dry method (*i.e.* by fusing the powdered ore with or without fluxes).

The wet method (*i.e.* by the agency of liquids).

In the principal wet assay, the ore is thoroughly dissolved in acids, and, by the addition of reagents, precipitates containing the metals are thrown down.

In some assays, particularly those of copper, iron, zinc, and silver, a standard solution of known strength is added to the original solution by allowing it to drop gradually from a graduated burette, and when a certain change of colour has been produced, by reading off the graduated mark at the top of the liquid column in the burette the amount of metal in the ore can be accurately determined by a slight calculation. At the same time more simple methods will, if not strictly accurate, give good results, and are more likely to be adopted by the prospector.

Then there is the assay by mechanical means (for instance, the separating of the lighter portions from heavier by means of water, as in the “panning out” of gold in a deposit), (see GOLD, Chap. V.).

In dry assays, crucibles or scorifiers capable of standing very great heat, without breaking, are generally used for

conducting the operations, and in these the powdered ores, with or without fluxes, are exposed to heat in a furnace, the temperature varying according to the nature of the ore.

The principal fluxes employed are :—

**Carbonate of Soda, or Potash**, which forms fusible compounds with silica, &c.

**Borax**, which forms fusible compounds with lime, oxide of iron, &c.

**Glass, Silica, Fluor-Spar, Litharge**, and others.

**Reducing Agents** are used, such as charcoal powder, cyanide of potassium.

**Oxidizing Agents**, such as atmospheric air (removing sulphur, &c., in the roasting process), nitre (which is very rich in oxygen), litharge, salt, &c.

**Desulphurizing Agents** (for removing sulphur), such as air (in the roasting process), iron nails, carbonate of soda, &c.

**Agents to remove Arsenic**, such as atmospheric air (in roasting process), nitre, &c.

**Collecting Agents** (for collecting silver or gold), such as lead, mercury, &c.

#### GENERAL TREATMENT OF ORES.

Specimens to be assayed should not be chosen to elicit a "good assay" only. They should represent dressed ore ready for shipment. When an average portion of rock has been selected, it should be carefully powdered, if possible, in a mortar, or, in the absence of a mortar, broken up into a few pieces; and these, rolled up in cloth or paper, should be powdered between two hard rocks. To prevent fragments from flying out of the mortar, a loose paper cover, with a hole in the centre for the pestle to pass through, will suffice. Some substances, especially those of a quartzy nature, will be rendered easier to crush by first being heated and thrown into water. If the ore does not contain metallic particles, the operation of powdering and sieving is comparatively easy; when, however, metallic fragments are mixed

up with the bulk of the ore, they are very apt to become flattened out by hammering, and do not always present a metallic appearance. In this condition they may refuse to pass through the sieve, and an inexperienced person, not understanding that they may be the most valuable fragments of the sample, is inclined to throw them aside. In reality, they should be collected together and most carefully examined.

When fragments of the ore adhere to the mortar, a little powdered coke or charcoal should be stirred about in the mortar.

When a dry assay or analysis is intended, the best sieve to use is the one of sixty meshes to the inch; when an ordinary wet assay, the eighty-mesh one; but for the separation of heavy metals, such as gold, tin, &c., from the lighter matter, by means of water and motion, the ore need not be powdered very finely. A piece of fine muslin will, in the absence of a sieve, answer ordinary purposes tolerably well, if, when the powdered ore be placed in it, the muslin be gathered together at the corners and shaken gently. After the specimen has been thoroughly powdered it should be put back into the mortar and stirred a few times by the pestle in order to evenly distribute the light and heavy particles, and then by a quick overturning of the mortar deposited on a piece of dry paper (glazed if possible). The powder may then be gently mixed by a knife or spatula, and if there be too much in quantity divided into quarters, and one or more divisions selected for the assay. The ore can then be weighed very accurately on the ore balance, after which it is ready for assaying. If the assay is one for gold and silver, the resulting button of precious metal is naturally very small (and to weigh which the very delicate button balance is used), so that great accuracy in the original weighing of ore is necessary, as the following calculation has to be made:—If a weight of ore yields a certain weight of metal, what weight of metal in ounces will a ton of similar ore yield? If the ore is assayed for ordinary metals, such as lead, &c., then

$$\frac{\text{weight of resulting metal}}{\text{weight of sample of ore}} \times 100 = \text{percentage of metal in the ore.}$$

For weighing gold, silver, or platinum, the troy weight is sometimes used; for weighing other metals, avoirdupois. The French decimal system of grammes and decimals of a gramme is convenient for both. (See APPENDIX.)

The management of the button balance requires very great care, and should never be used except for the precious metals, as the ores, fluxes, &c., must be weighed on a less delicate balance. To adjust and thoroughly understand the reading of the button balance needs instruction, and no one should use one until the working of it has been explained. It may be well, however, to mention that the glass slide should always be kept down except during the weighing operation, and that the apparatus should never be by any means exposed to acid or other deleterious fumes.

A very good plan is to use the conventional assay ton weights in weighing the ore, as, by this conventional system, the number of ounces of precious metal in a ton of ore may be known according to the amount of milligrammes, &c., the button of precious metal weighs.

Thus, in America, a conventional assay ton (A.T.) weighing 29.166 grammes may be used (where 2,000 lbs. = 1 ton); or in British countries one weighing 32.667 grammes (where 2,240 lbs. = 1 ton). Still, there is no occasion to know the exact weight of the piece of metal used as an A.T., so long as the operator knows how to read a balance where A.T.'s are made use of.

If 1 A.T. of ore yields a button of 1 milligramme, a ton of ore yields 1 oz. troy of precious metal.

One-tenth A.T. is a very convenient quantity of ore to take; for if the button weighs  $x$  milligrammes, this represents  $10x$  oz. of precious metal per ton of ore.

In the absence of a proper balance, the following may be of service:—

Procure from a carpenter a very thin strip of pine wood (about one foot or fifteen inches long and one-third of an inch wide). Place a fine needle across by means of wax, or through the middle. Next obtain a piece of sheet tin or other metal (one inch by half-inch), and bend its edges up perpendicularly one quarter-inch on each side. On these upturned portions place the needle ends. Should the beam

not balance properly, trim either end by shaving off very thin pieces until it does. Now divide the strip into twenty equal parts, *i.e.* ten on each side of the middle, and mark them 1, 2, 3, &c., so that the 1 marks may be nearest the middle and the 10 marks at the ends.

Three weights are required :—

One grain : Can be obtained by weighing out a piece of thin brass wire (ends bent together) on a chemist's balance.

One tenth grain : To obtain this, place the one-grain weight on the 1 mark of the wooden balance and place such a smaller piece

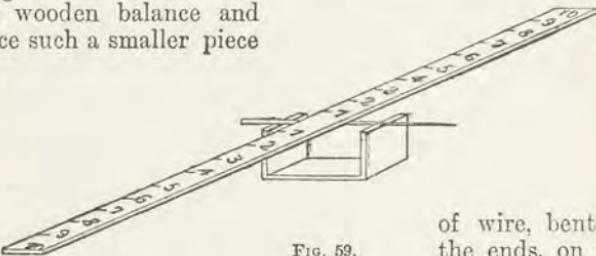


FIG. 59.

of wire, bent at  
the ends, on the  
10 mark on the

opposite side, as will cause the beam to balance properly.

One-hundredth grain : To obtain this, place the one-tenth grain weight on the 1 mark, and a piece of thread or such like material on the 10 mark on the other side as will cause the beam to balance properly.

#### To weigh the Button of Gold or Silver.

Place it on the 10 mark and see if 1 grain on 10 mark (opposite side) exactly balances it; if it does, the button weighs 1 grain. If the wire weight be too much, move it towards the middle of the beam to a division, until it is a little lighter than the button. Leave it on this mark. Then take the one-tenth grain, and, commencing from the end of the beam, move it towards the middle until the division reached is that one where this weight together with the first weight is just lighter than the button. Then proceed with the one-hundredth grain in the same way.

Suppose, now, that the one grain weight be at 8, the one-tenth grain at 7, and the one-hundredth at 3, the weight of

the button is .873 grains, that is, a little more than eight-tenths of a grain. A rule of three sum then determines the amount of precious metal per ton of ore.

If a certain weight of ore yields eight-tenths of a grain, how many grains will there be in a ton of similar ore? (N.B. There are 32 666 troy ounces in one ton.) The number of ounces of precious metal in a ton will be known.

#### DRY ASSAY FOR SILVER AND GOLD.

In a gold and silver assay, the precious metals in the sample, either by the scorification or "fusion in a crucible" method, have to be absorbed by lead, and the resulting button of lead containing the gold and silver has to be cupelled in the muffle; the final result being that the precious metals are left on the top of the bone-ash cupel as a shining globule.

As an assaying apparatus or "outfit" is to be obtained complete in a chemical apparatus shop, there is no occasion to enter into too much detail, the portable furnaces manufactured for cupellation in a muffle being made expressly for prospectors and assayers. The most necessary articles are the following:—

An ore and button balance with weights, two or three muffles, Hessian crucibles, scorifiers, cupel mould, crucible, scorification and cupel tongs, pokers and scrapers, an iron pestle and mortar (or a plate and rubber), box sieve (80 mesh), spatula, hammer, bone-ash for making cupels, litharge, borax, carbonate of soda, iron nails, nitre, coke, charcoal, &c., test tubes, acids, brush for cleaning the buttons.

*To light the fire.*—First, place some dry twigs and paper or wood shavings or chips, and above this slightly larger wood round about the outside of the muffle, and set light to it. Then throw in pieces of charcoal, coke, or anthracite coal broken into small pieces about the size of hen's eggs. Shut the mouth of the muffle and the grate door. Raise the temperature as high as possible for the scorification process.

Though fusion in a crucible is very convenient for poor gold and silver ores, inasmuch as a greater charge can be

used at once than in a scorifier, the scorification process is, however, the usual one for ordinary ores.

#### Assay of Gold and Silver Ores by Scorification:—

Charge—Finely powdered ore . . . . . 50 grains.

\*Granulated lead 500—1000 "

Borax . . . . . 5 "

Half the lead should be mixed with the powdered ore and placed in the scorifier; the other half should be spread over this, and the borax on the top. The scorifier may then be placed in the muffle and the door closed until fusion is complete. Then the door may be partly opened and the temperature raised until the surface is covered with litharge, the whole time being about half an hour. The scorifier can then be taken out by the tongs and the contents carefully poured out into an iron cup or mould. When cool, the button of lead (which contains the gold and silver) should be detached from the slag, cleaned by hammering, and then, in the shape of a cube, is ready for cupellation.

If Fusion in a Crucible be desirable, the following formulae are to be recommended:—

For ore, chiefly of rock—

Charge—Ore . . . . . 100 to 500 grains.

Red lead . . . . . 500 "

Charcoal powder . . . . . 20 to 25 "

Carbonate of soda and borax 500 " together.

The more quartz in the ore, the more carbonate of soda should be used; the more iron and other metallic bases,

\* Lead used in assaying should always be, in the first instance, cupelled, in order to find out whether it contains any silver mixed with it, which it usually does. The number of parts of granulated lead used varies according to the nature of the ore. Comparatively pure lead can be obtained by heating litharge or red lead with  $\frac{1}{20}$ th the weight of charcoal. Even then the lead ought to be assayed for silver before using it in the cupellation process.

<i>Character of ore.</i>	<i>Parts test lead.</i>	<i>Borax.</i>
Quartz.	8	$\frac{1}{4}$ th to 1.
Galena.	6	$\frac{1}{3}$ th.
Arsenical, antimonial, iron or copper pyrites ores.	10—16	$\frac{1}{15}$ th to $\frac{1}{8}$ th.

the more borax. The ingredients should be well mixed together and a little borax placed on the top. The crucible should be heated, though not too rapidly at first, until the contents are quite liquid. This will take about twenty minutes. After which it may be removed and the contents poured into the iron mould. When cool, the lead button should be detached from the slag, cleaned, and beaten into the shape of a cube; it is then ready for cupellation.

Fusion for silver and gold bearing copper ores and sulphides. Weigh the ore and roast it before fusion is commenced :—

Charge—Ore . . . .	100 to 500 grains.
Red lead . . . .	1000 "
Charcoal powder . . . .	35 "
Carbonate of soda . . . .	200 to 3000 "
Borax . . . .	150 to 300 "

### Cupelling.

While the muffle is in the process of heating, place the empty cupel (to make which see page 119) inside, and when the proper temperature of the furnace is reached, known by the cherry-red colour, gently, by means of the cupel-tongs, place the lead button (containing the gold and silver) obtained from the scorification or "fusion in the crucible" method into the concave hollow of the bone-ash cupel. Close the door of the muffle until the temperature of the fused metal is the same as that of the muffle. The behaviour of the assay can be observed through a slit at the side or top of the door. The assay must not be allowed to "freeze" ("freezing" is known by the fumes ascending right to the top of the muffle), nor must it be too hot (being too hot is known by the fumes scarcely rising at all, and the outline of the cupel being indistinct). If inclined to "freeze," a piece of charcoal may be put into the muffle to increase the heat, and the fire stirred. When the proper temperature is attained, the fumes from the cupel should reach about half-way up the height of the muffle, the cupel should be red, and the metal very luminous, while a stream of fused matter circulates about on the surface of the molten

liquid. The button gradually becomes more convex, and at last a mirror-like speck of bright silver or gold, or both, is left. The cupel should then be gradually drawn by means of the cupel tongs to the muffle door, so that the metal may not "spit," which it might do were the cupel to be too suddenly cooled in the cold air. In form the little button should, if a proper one, be well rounded, crystalline below, and easily detached from the cupel. As the button may contain both silver and gold, it should, after being cleaned by brushing with a paint brush and weighed, be removed and subjected to the action of nitric acid, in order that the silver may be dissolved and the gold left in the form of a dark powder; after this the gold may be weighed, and the original weight of the button, minus the weight of the gold, will represent that of the silver.

N.B.—To separate the two metals in the button, place the button in a test tube with about ten times its weight in nitric acid (dilute), and boil for about a quarter of an hour; the silver will be dissolved and the gold left. The liquid should be decanted, a little pure nitric acid poured on the gold powder to make sure that no silver remains, and the liquid poured off and the gold washed and dried. If the appearance of the button suggests that it is rich in gold, some silver must be fused with it before acid is poured on, as unless there be three times the amount of silver as gold, the "parting," as the above process is called, will be incomplete.

Indications of the presence of metals in the ore known by cupel stains:—

*Antimony*—pale yellow to brownish red scoria; sometimes the cupel cracks. *Arsenic*—White or pale yellow scoria. *Cobalt*—dark green scoria and greenish stain. *Copper*—green or grey, dark red or brown. *Iron*—dark red brown. *Lead*—straw or orange colour. *Manganese*—dark bluish black stain. *Nickel*—greenish stain; scoria, dark green. *Palladium and Platinum*—greenish stain; the button will be very crystalline. *Tin*—grey scoria; tin produces "freezing." *Zinc*—yellow on cupel; the cupel is corroded.

### To prepare Bone-ash Cupels.

The ash of burnt bones (that of the sheep or horse is preferable) should, in not too fine nor too coarse a state, be mixed with water (about an ounce of water to a pound of bone ash), so that it may, when of the proper consistency, adhere together when pressed, although not stick to the fingers. Place a metal disc—a coin if it fits well—into the bottom of the cupel mould, and then fill the cavity with bone-ash; place the hammer with the convex base on the top of the ash and give it a smart blow by a mallet or other hammer. The cupel can then, by means of the finger, be pushed uppermost and out of the mould.

### Assay for certain Metals other than Gold or Silver.

To find the amount of lead in Galena, the usual lead ore.

Charge—powdered ore, two or three times the weight of carbonate of soda, three iron nails (tenpenny) placed in the top for taking up the sulphur, and a cover of salt or borax.

The assay may be conducted in a muffle or other furnace.

The crucible—two-thirds full of ore and fluxes—should be heated to redness, and the temperature gradually raised until the operation is finished, which will be in about twenty or twenty-five minutes.

The contents of the crucible are to be poured into a mould, and, when cool, the lead button separated from the slag.

$$\frac{\text{Weight of button}}{\text{Weight of ore sample}} \times 100 = \text{percentage of metal.}$$

As galena always contains more or less silver, the resulting button ought to be assayed for the precious metal in the cupel. As a cupel does not conveniently absorb much more than its own weight of lead, the button may have to be divided into two or more portions, and each of these cupelled separately.

Galena may be roughly assayed for lead by placing the powdered ore, without fluxes, in an iron dish, and exposing it to the heat of a blacksmith's forge.

To assay Copper ores by the crucible method, including the refining process, requires much practice, and for this reason the "wet assay" is the more suitable for obtaining an approximate estimation of the amount of metal in a copper ore.

#### Assay of Tin Ore.

If the ore be poor, it ought to be concentrated, the vein-stuff being got rid of as much as possible. If mixed with iron or copper pyrites, it ought to be calcined or else treated with acids. One method is, as in Cornwall, to mix the ore with one-fifth of its weight of anthracite coal or charcoal, and to expose it in a crucible to a great heat for about twenty minutes. The contents are then poured out into an iron mould, and the slag carefully examined for buttons.

Another method is to mix 100 grains of the ore with six times its weight of cyanide of potassium, and expose the mixture to the heat of a good fire for twenty minutes. The contents are allowed to cool, and afterwards broken to remove the slag. The buttons are then weighed.

To assay Mercury ores, see MERCURY, Chapter V.

#### Antimony.

To determine the amount of antimony in an ore containing sulphide of antimony and more or less vein-stuff:—

Place about 2,000 or more grains of broken-up ore in a crucible, the bottom of which is perforated, and the hole in which is partially closed by a small piece of charcoal. Now fix the bottom of this crucible into the mouth of another crucible, so as to be about half-way down its depth. Then lute\* the lid and also the joint between the two crucibles with fireclay and sand. By placing the lower crucible under the furnace bars and the upper one above, the heat of the furnace will cause the sulphide of antimony, which fuses at a red heat, to collect in the lower crucible, while the quartz and other matter will remain in the upper one. The operation should take about an hour and a half.

\* A dough of fresh fireclay and ground firebricks is a good lute.

When pure, sulphide of antimony contains a little more than 70 per cent. of metal.

## WET ASSAYS.

### Gold.

Powder about half an ounce of ore. Add four times its weight in a mixture of 4 parts hydrochloric and 1 part nitric acid, in an evaporating dish or other apparatus. Evaporate the decanted solution to dryness, hydrochloric acid being added as evaporation proceeds. Add sulphate of iron, dissolved in water, to the gold solution, both being previously warmed. The gold is precipitated as a brown powder. Filter the solution and weigh the dry precipitate.

This method, however, is not to be recommended so much as the dry assay.

### Silver.

Dissolve the powdered ore in nitric acid, and throw down the chloride of silver precipitate by adding a solution of common salt or else hydrochloric acid.\* If chloride of lead and mercurous chloride are absent, the solution may be decanted or filtered, and the chloride of silver weighed : three-quarters of the weight very nearly represents pure silver. Or else the chloride of silver may be fused and the metallic silver collected and weighed.

### Lead.

Place the powdered ore in a porcelain dish or other convenient and suitable apparatus, and thoroughly dissolve it in strong nitric acid by heat until the residue is nearly white and red fumes cease to be given off. Add a few drops of sulphuric acid and evaporate to dryness ; then add water, and filter. As silica and certain sulphates may be in the residue, boil it along with carbonate of soda for about forty minutes. Filter. Dissolve the residue—carbonate of lead, &c.—in acetic acid. Add a little sulphuric acid to the

\* Ammonia added to the precipitate would dissolve the chloride of silver, would blacken the mercurous chloride, and would not alter the chloride of lead.

solution. Filter or decant the solution. The residue—sulphate of lead—nearly represents 68 per cent. of metallic lead.

### Copper.

The most accurate method of determining the amount of copper in an ore is to thoroughly dissolve the ore in acid, then to add ammonia until a blue colour is obtained, and then to drop from a graduated burette a standard solution of cyanide of potassium until the solution has the colour taken out of it.

Number of markings on burette : present reading :: known strength of solution :  $x$  where  $x$  is the number of grains of copper in the weighed portion of the ore.

$$\frac{x}{\text{weight of ore}} \times 100 = \text{percentage of copper in the ore.}$$

The burette method, like the dry assay, requires great care in order to insure accuracy, and might mislead one who has not studied and practised it, as certain metals other than copper may sadly affect the results. On this account there is no occasion for explaining the process in detail, as the prospector will find the following method comparatively simple.

Take finely powdered ore, say 25 grains, drive off sulphur, &c., by roasting (q.v.) in a porcelain dish.

Dissolve by heating in nitric acid. Add a little sulphuric acid and evaporate to dryness. Dilute in water and pour the solution into a basin. If well polished sheet or other iron be placed in it, and left for an hour or so, the metallic copper will form on its surface, and by means of a feather may be rubbed off and weighed.

Or else (to avoid roasting). Moisten the powdered ore in sulphuric acid, and add nitric acid. Let it be thus heated for about an hour or so, and let nitric acid be constantly added during the operation. Add hydrochloric acid to get rid of nitric acid, which may be judged by absence of chlorine smells. Dilute with water and obtain copper on the inserted iron as before. To see that all the copper has been properly deposited, dip the polished point of a knife-

blade into the solution ; if it has not, a film of copper will be left on the knife.

$$\frac{\text{Weight of copper}}{\text{Weight of ore sample}} \times 100 = \text{percentage of copper in the ore.}$$

### Iron.

To assay an iron ore by the wet method, the standard solution of bichromate of potash is, by means of a graduated burette, added to the iron solution (the powdered ore dissolved in hydrochloric acid) ; but like the other burette assays, this requires so much practice in order to secure reliable results, that there is no occasion to enter into details concerning it. The prospector will rarely require to know the exact amount of iron in an ore, and his own sense will perhaps guide him nearly as well as an assay, as great quantity and good quality are both necessary to make an iron ore payable.

### Roasting.

In roasting the powdered ore much care is necessary in order that the sulphur, &c., may be expelled. The powdered ore placed in an open and shallow vessel, if possible, should be exposed to a low heat at first, and after a time the temperature may be raised. During the operation free access of air is requisite, and the ore must be constantly stirred by means of an iron wire bent at one end, or other suitable apparatus, so as to prevent clotting. When fumes cease to be given off the operation is finished, about a quarter of an hour being the usual time necessary.

### Mechanical Assay of Ores.

This is performed by crushing the ore and subjecting it to the action of water. If the powdered ore be subjected to the action of water running on an inclined plane or trough with a slope, the heavier particles of metals may be caught up in their descent by means of thin boards (riffles) fastened across the trough. Rough hides, with the hair upwards, may be used to intercept the heavier portions. To "pan" gold, see GOLD, Chap. V.

## CHAPTER X.

### *TREATMENT OF ORES.*

Metallurgical treatment.—Copper from copper pyrites and other sulphides.—Lead from galena.—Treatment of silver-bearing ores.—Gold from lodes and deposits.—Concentration of ore.

IN the laboratory metals are obtained from minerals by either the wet or dry process, as briefly referred to in Chap. IX.

If a mineral be dissolved in an acid or acids (N.B. Chloride of silver, tinstone, &c., are, however, nearly insoluble in acids), and reagents added, precipitates result; and from these the metals can, by fusion or otherwise, be obtained; or, by the addition of certain metals to certain of the solutions, other metals can be precipitated :—

Iron precipitates lead ;

Iron or zinc precipitates copper ;

Copper, zinc, iron, lead precipitate mercury ;

&c., &c.

A few of the fusion methods have already been described; but for the treatment of ores on a large scale many of the processes adopted in the laboratory are too costly, and, for this reason, though the principles of extraction may be the same, economy is of the utmost importance. The apparatus employed must be considered with regard to its original price, durability, efficiency, portability (in some instances), utility with respect to its being a labour-saving apparatus, and as a means of reducing the price and quantity of fuel, fluxes, and other requisites to a minimum. The cheapest fluxes, such as limestone (not, however, cheap in some countries where freightage is expensive), and comparatively cheap chemicals have to be used where expensive substitutes would be out of the question. So, too,

where fuel or water is absent from the immediate neighbourhood of a mine, or when the locality is at a distance from civilisation, there are many points of importance which arise when the adoption of any particular plant or process has to be decided upon. A very great deal of thought has for many years, and is now, being bestowed in finding out more effectual and cheaper ways of dealing with silver and gold-bearing ores. Many a mine has to be closed on account of bad management, of its too great working expenses, or due to inability of a process to secure all the valuable metal in the ore. Certain it is that in different parts of the world, such as Western America, South Africa, &c., there is an immense quantity of what to-day is called low-grade ore, which, under favourable circumstances, at a future date, may be turned to profitable account; and which now might be worked if only the cost of treatment per ton of ore could be reduced by a few shillings, and which, so far as quantity and average quality are concerned, might be more lasting than many of the high-grade ore-bearing mines, which not unfrequently are "patchy." It is not the place here to lengthily describe the different processes by which the various metals are extracted from their ores; for instance, that of obtaining iron from its oxides by means of carbon, carbon monoxide, hydrogen, &c.; or how the carbonates have sometimes, in the first instance, to be calcined to reduce them to the state of oxides; or of obtaining zinc from the sulphide by roasting, heating with carbonaceous matter, and by distillation; or of mercury (from cinnabar) by heating in air, or with lime, or iron oxide, and distillation; or of obtaining antimony from its sulphide by means of scrap iron, &c.

At the same time the prospector may derive some interest, if not benefit, by knowing a few of the principles which, practically applied, are dealt with in metallurgy.

The various methods undergo much alteration and modification in not a very long space of time. As an example of this may be cited that of aluminium. The sodium process of not long ago has been quite replaced by electrical methods, which have very greatly reduced the price of the metal.

So it is impossible, just as it is unwise to state which is

the best one for treating any particular kind of metalliferous ore. Besides, that which suits an ore in one locality may be quite unsuitable, for reasons already explained, for that in another.

Perhaps the best way to approach this subject of metallurgy is to consider one of the methods which may be rightly termed complex, viz., extraction of copper from copper pyrites.

#### Copper from Copper Pyrites and other Sulphides.

Calcination (to get rid of sulphur, arsenic, &c.); fusion with "metal slag" (containing a proportion of silica, iron oxide, &c.) and other copper ores, in order to obtain a regulus or matte (which contains sulphides of copper and iron); calcination of the crushed regulus; fusion of this to get rid of iron (in this process copper oxide or carbonate is added, also certain slags which contain silica, &c.); roasting of the regulus to obtain blistered copper.

This process depends on the fact that copper possesses for sulphur a greater affinity than iron does. Thus when a mixture of the oxides and sulphides of iron and copper are fused together the iron combines with the oxygen and the copper with the sulphur, a mixed sulphide of the two metals resulting if there is not sufficient oxygen present to combine with the whole of the iron. The iron oxide so produced can be slagged away by the aid of silica, and the copper collected, more or less free from iron, in the form of a fused sulphide regulus.

There are two main methods of copper smelting—the reverberatory and the blast furnace methods. In the former the copper sulphide produced in the above manner is partially roasted to oxide, and the oxide so formed allowed to react on the residual sulphide, metallic copper being the result.

In the other, the nearly pure sulphide—"white" or "pimple metal"—is roasted almost completely to oxide, which is then reduced by the aid of carbon in some form.

The wet methods are mainly two. In the one the copper sulphide is roasted to sulphate, which can then be extracted with water, the copper being afterwards precipitated by

iron. In the other, the oxide ore, containing some sulphur, is roasted with common salt, cupric chloride resulting, which can be leached out by the addition of water, the residues being subsequently extracted by the hydrochloric acid, which forms a bye product of this process.

To extract lead from galena, in a manner akin to that referred to in assaying, is a comparatively simple process. To do so, however, in the most economical manner, many operations and much plant may be necessary, the very lead fumes being in some instances turned to account. It must be remembered that galena contains silver, not always in such quantity as to demand much consideration; but frequently the reverse: indeed, often a galena ore may be only valuable for its silver. As the lead obtained from the smelting furnace contains also the silver (and gold), the cupellation process, the principle of which has been mentioned in page 117, or other methods are made use of to obtain the precious metals.

In the Pattinson process, with the various ladlings from one pot to another, the principle involved is that when a lead-silver alloy is allowed to cool slowly, crystals of lead separate out, and these are very poor in silver, this metal becoming concentrated in the residual "mother liquid."

In the Parkes method, which now is much made use of, metallic zinc is stirred into the lead, and, this cooling down, the zinc rises to the top and solidifies. It is then found to contain both the silver and gold originally in the lead.

#### Treatment of Silver-bearing Ores.

The extraction of silver from certain lead ore has been referred to in the foregoing remarks. When the ore is a carbonate, the ore can be smelted with oxide of iron and limestone to obtain all the lead with the silver.

Some silver-bearing ores containing sulphides are treated after the manner referred to in the description of the treatment of copper ores, so that there may be obtained a regulus, which may either be roasted direct to form sulphate, the silver sulphate being washed out with water (Zier vogel's method). In the Augustin method, the ore is roasted with salt, the silver chloride extracted by brine,

and the silver thrown down from the solution by some metals, such as copper. In the Von Patera method, so largely used in practice, after roasting with salt, the ore is leached with a weak solution of sodium hyposulphite, the silver being afterwards thrown down from this solution by a soluble sulphide.

In the process whereby the silver-bearing ore is roasted, and a sulphate of silver dissolved by water and the silver precipitated by means of copper, the residue may have to be smelted with addition of gold-bearing pyrites, to obtain a matte in which the gold and silver are retained.

In the Mexican process, the sorted silver ore (native silver, sulphide, and chloride of silver) is placed in heaps with common salt, for a while, then ground with magistral (derived from roasted iron-and-copper sulphides) and mercury.

There is no occasion, however, to extend this subject, suffice it to say that the foregoing methods will give an idea as to some of the principles involved.

The following table will show certain conditions under which the Pan amalgamation and Hyposulphite leaching means are adopted :—

Pan amalgamation	$\left\{ \begin{array}{l} \alpha \text{ Direct.} \\ \beta \text{ After roasting with salt.} \end{array} \right.$
Hyposulphite leaching	$\left\{ \begin{array}{l} \alpha \text{ Direct or after roasting with salt.} \\ \beta \text{ Using a mixed solution of copper and sodium hyposulphite (Russell's process.)} \end{array} \right.$

#### Gold from deposits and lodes.

When the gold is "free" in alluvial deposits, sluices, cradles, &c., washing down of matter by hydraulicing, &c., are made use of.

When the gold is free in lode matter, the ore is usually stamped very finely, and amalgamation with mercury, as the gold, &c., is washed down inclined planes, &c., the amalgam being eventually squeezed through chamois leather, blankets, canvas &c., to get rid of the superfluous mercury,

and the residual mercury with gold being then retorted to leave only the gold behind.

Auriferous ore with sulphides may firstly be roasted and then treated with mercury. At the same time such a procedure is not always economically satisfactory, especially when there is a coating of any foreign metallic compound around the gold.

The following summary will afford an idea of some of the methods applicable :—

Pyrites and refractory materials.	$\alpha$ Chlorination process.* $\beta$ Cyanide $\gamma$ Amalgamation after roasting. $\delta$ Concentration in metallic lead, metallic copper, or in a mixed regulus or in iron sulphide.
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In the Chlorination process, chlorine gas, which has a great affinity for gold, is generated and unites with the gold to form a chloride of gold, which is then dissolved by water, and the precious metal precipitated by means of sulphate of iron or other agent. There is no occasion to enter fully into an account of the process, suffice it to know that whether black oxide of manganese with salt and sulphuric acid, or chloride of lime and sulphuric acid, or chloride of lime with another agent, not a free acid, sea salt or salt water and lime, salt and caustic lime, are used, the object is to attain the most efficient way of obtaining the gold as a chloride.

In the cyanide process, much used in the Transvaal, &c., for obtaining the gold from tailings, a solution of cyanide of potassium is used for the purpose of seizing the gold, to form a cyanide of gold compound, which is passed over metallic zinc, or otherwise treated, whereby the gold is deposited.

It must be borne in mind, that any new chemical process, before being used, should be well investigated as to its suitability. One may not be advisable, if the gold is in too

\* This process is much used in the Transvaal for the treatment of sulphide concentrates.

coarse a state, or when the presence of another metal or metallic compound, such, for instance, as copper, might interfere with the operation. In such a case, the agent might attack such ingredient of the ore, rather than the gold, unless means were adopted to obviate this. A thorough analysis of samples of ore should be always made, and the merits and demerits of a proposed process thoroughly investigated by someone of experience, before any particular "plant" is constructed, or any method adopted for the treatment of the ore in a mine.

Sometimes more than one process is advisable in the treatment of ore; for example, as often is the case in the Transvaal, the crushed quartz may be first subjected to the amalgamation process, the sulphide concentrates to the chlorination, and the tailings to the cyanide. Especially is this the case where such minerals as antimony, sulphide, zinc blende, and other sulphides, are present in quantity. Very frequently such ores, though they may assay fairly well for gold and silver, cannot be smelted profitably, especially in out-of-the-way districts, where everything—freightage, fluxes, labour, &c.—is expensive.

In the foregoing remarks no notice of that which frequently constitutes one of the chief elements of success in the prosperity of a mine, viz.: concentration, has been taken.

The concentration may be applied, for instance, in the collection of the heavier portions of the ore, crushed finely or coarsely, and is applicable not only to the ore before any other operations take place, but also to the "tailings." It is effected sometimes by one machine, sometimes by several, classification of the ore being made with regard to size or weight of the small particles of pieces of ore.

Just as the heavy grains sink to the bottom of the gold-washer's "pan," so, on a larger scale, do they in the "tossing tub," the "dolly," or "kieve."

So if mixed, finely divided ore or sand, containing, for example, all sorts of minerals, such as gold, iron compounds, &c., copper pyrites and earthy matter or quartz, be shaken together with water, the lighter matter settles down above the "heavier."

In the ordinary "jigging" apparatus a sieve containing broken or crushed ore is worked up and down in water, or has water pushed through from underneath, and the heavier parts which do not fall through the meshes, follow the same law as the above. Thus with a series of "jiggers," each at a lower level than the next, and kept in motion by means of an eccentric or revolving crank, the "stuff" can be not only "sized" but also sorted as to weight of particles.

Another plan of concentration is that of allowing running water to wash the ore along an inclined plane, as in the ordinary amalgamation tables, or in the "Broad Tom" or "Long Tom" sluice (natural or artificial); and the same principle—that the lighter portions are washed farther down than the heavier ones which remain near the top—applies to the "buddle" for treating slimes or finely divided ore. In the simplest form of "buddle" the ore is passed through a vertical passage on to the apex of a cone with slightly inclined sides, the heavier matter settling near the apex.

It is unnecessary to describe the many various kinds of concentrators which have been or are being used. Mention, however, may be made of the well-known Hendy's concentrator, in which the oscillating shallow pan is constructed in a specially designed curve towards the centre. In this apparatus the heaviest portions sink to the bottom and the lighter flow through an outlet in the centre.

In the Frue Vanner, a shaking motion is imparted, the finely divided matter being placed on the upper end of a revolving band. In "percussion" tables the action of water and percussion causes the heavier matter to be retained at the head of the table and the lighter farther removed. To classify mineral matter according to size, the ordinary sieve, trommels (revolving sieves, cylindrical, conical, single, or continuous), are much used for coarsely broken ore.

There are other classifiers in which the varying velocity of the grains in water, &c., are made use of, and in some concentrators atmospheric assistance and gravitation, and also centrifugal force, play a part.

## CHAPTER XI.

### SURVEYING.

To calculate areas.—To find the distance from an inaccessible place.  
—To solve problems in connection with adits, shafts, lodes of a mine.—Position of a shaft with regard to a lode.

In ordinary surveying, a Gunter's chain 66 feet long, and consisting of 100 links, each tenth one of which has some distinguishing mark attached, is very frequently used for measuring lengths. When the number of square links in a piece of ground is known, this divided by 100,000 (the division being performed so easily by striking off five figures from the right hand side to the left) will represent the number of acres in the area.

To find how many acres there are in a rectangular piece of ground, multiply the length in links by the breadth in links, and divide the result by 100,000.

*Example.*—Find the area in acres of a rectangular piece of ground, the length of which is 1,225 links (that is, 12 chains and 25 links), and the breadth 150 links (that is, one chain and a half).

12 chains 25 links.



FIG. 60.

$$\begin{aligned}\text{Number of acres} &= \frac{1225 \times 150}{100000} \\ &= 1.83750 \text{ acres.}\end{aligned}$$

The number of roods in the .83750 of an acre may be found by multiplying this by 4 and dividing by 100,000; the number of poles, by multiplying the remaining decimal by 40 and dividing by 100,000. Thus :—

$$\begin{array}{r} .83750 \\ \times 4 \\ \hline 3.35000 \\ \times 40 \\ \hline 14.00000 \end{array}$$

= 3 roods 14 poles.

Therefore the whole area = 1 acre, 3 roods, 14 poles.

To find the area of a triangular piece of land, find the area of the triangle in square links and divide by 100,000.

To find the area of a triangle in square links, multiply the length of the base by the length of the perpendicular from the opposite corner to the base and divide the result by 2.

*Example.*—Find the area of the piece of land A B C.

Set up poles at A B C. Measure B C. Travel from B towards C until a point D is reached where the line A D seems to be at right-angles to B C. Measure A D.

Suppose B C = 1200 links ; A D = 168 links.

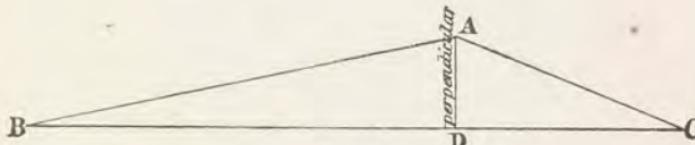


FIG. 61.

$$\text{Area in acres} = \frac{1200 \times 161}{2} \times \frac{1}{100000}$$

which worked out as in the last example will give  
1 acre, 3 roods, 29 &c. poles.

To find the area of a piece of land indicated by the figure A D C B. Measure B D. Then find areas of triangles A D B, B D C, as in the last example.

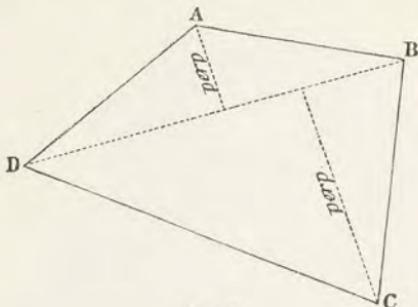


FIG. 62.

The whole area equals the area of the triangle A D B added to that of the triangle B D C.

Similarly, to find the area of a tract of land A B C D E.

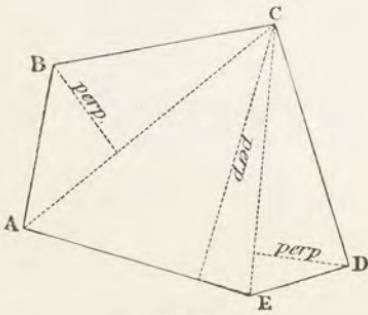


FIG. 63.

The whole area equals the area of the triangle C D E, plus that of A C E, plus that of A B C.

In any of the above calculations, should the measurement be by yards and feet, the number of square yards in the land divided by 4,840 will give the number of acres. (See Measures, APPENDIX.)

To find the distance between the points where one is inaccessible from the other—for instance, on the other side of a river.

Required the distance between B and A.

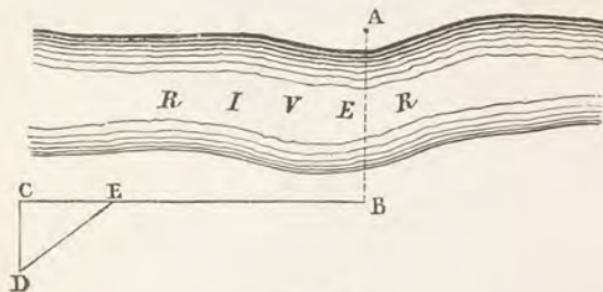


FIG. 64.

Pace off from B, at right-angles to the direction B A, a distance B E; then continue pacing off a distance E C, so that E C may be some even fraction of B E (say one-fourth or one-eighth). Proceed, at right angles to C B, along C D until a point D is reached, where D E A seem in one and the same straight line.

Then :—

$$\text{Required length A B} = \frac{C D \times E B}{E C}$$

Very frequently the prospector may wish to form some idea of the length of an adit necessary to meet a perpendicular shaft sunk from a certain known spot, or the length of a vertical shaft necessary to be sunk to meet an adit driven in from a certain point. To solve such problems (as well as many others in connection with surveying) a very limited knowledge of the properties of a right-angled

triangle, together with a Table of Sines (see Appendix), may prove useful.

Let  $\triangle ABC$  be a right-angled triangle.

(i.) Perpendicular  $AB$  equals length  $AC$  multiplied by  $\sin c$ .  
 Base  $BC$       "       $AC$       "       $\sin a$ .

Let  $AC$  represent two points on a hill-side, from which respectively a shaft,  $AB$ , is to be sunk, and an adit,  $CB$ , driven. Let  $B$  be the point where they may be supposed to meet. Measure length  $AC$ , and suppose it to be 200 feet. Measure either the vertical angle  $a$  (which is really  $90^\circ$ —the dip of the hill-side) or else the angle  $c$ , which is the dip.

Let  $a = 50^\circ 30'$ ; and  $c = 39^\circ 30'$ .

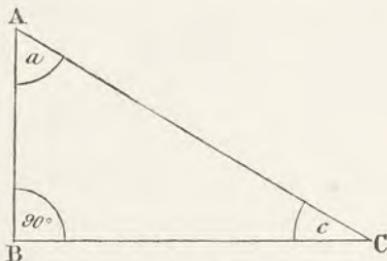


FIG. 65.

Then by (i.)—

Perpendicular  $AB$  equals 200 feet  $\times \sin 39^\circ 30'$ .  
 "       $BC$       "      200      "       $\times \sin 50^\circ 30'$ .

Now by Table of Sines,  $\sin 39^\circ 30'$  is .6361,  
 and,  $\sin 50^\circ 30'$  is .7716.

Therefore : perp.  $AB$  equals 200 feet  $\times .6361$ .  
 base  $BC$  equals 200 feet  $\times .7716$ .

That is : perp.  $AB$  is 127.22 feet,  
 base  $BC$  is 154.32 feet.

The length of the shaft is 127.22 feet, and that of the adit 154.32 feet.

Should the hill-side A C E G be irregular, such as in Figure 66.

Then A C, C E, E G, should be measured from convenient points, A, C, E, G. To find the length of shaft A O, find the lengths of A B, C D, E F, as in the last example. The whole length A O equals the sum of the lengths A B, C D, E F.

In the same way, the length of the adit O G equals the sum of the lengths B C, D E, F G.

Also, if any two sides of the right-angled triangle A B C are known, the third side can also be found without using the Table of Sines.

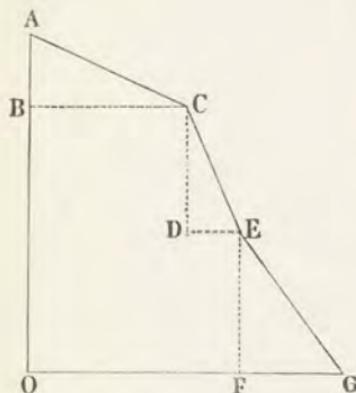


FIG. 66.

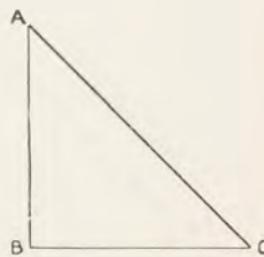


FIG. 66A.

$$\begin{aligned} \text{For } A C &= \text{square root of } (A B^2 + B C^2) \\ A B &= , , , \quad (A C^2 - B C^2) \\ B C &= , , , \quad (A C^2 - A B^2) \end{aligned}$$

Thus, supposing A C = 100 feet,  
A B = 80 feet,

B C would equal the square root of  $100 \times 100 - 80 \times 80$ , that is, square root of 3600, that is, 60 feet.

If it is required to know how deep a shaft will have to

be sunk, or how long an adit driven, to strike a lode whose inclination to the hill-side is known, certain properties belonging to any triangle and a reference to the Table of Sines will suffice. Let  $A B C$  be a triangle where  $A C$  represents the hill-side,  $A B$  the lode,  $C B$  an adit. Let the length  $A C$  be known, and also the angles  $a$  and  $c$  (and therefore the angle  $b$ , which is  $180^\circ$  — the sum of angles  $a$  and  $c$ ). Suppose it be required to know how far the adit will have to be driven to cut the lode and also the depth of the lode.

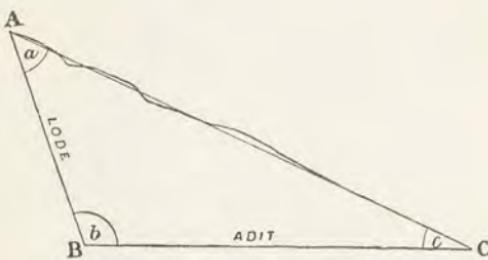


FIG. 67.

By a property of a triangle,

$$\text{Length } B C = \frac{A C \times \sin. a}{\sin. b}$$

$$\text{Also, length } A B = \frac{A C \times \sin. c}{\sin. b}$$

The question, Where ought a shaft to be sunk? has to be decided on as soon as development work is contemplated; and though the question depends in some measure on the nature of the country, rock, and other considerations, the following general hints may be useful.

If the lode dips in the same direction as the hill-side, the shaft ought to be as in Fig. 68, A.

If the lode dips contrary to the slope of the hill, then either the shaft should be sunk on the lode or higher up than the outcrop, or else below the outcrop, so that cross-cuts can be driven (Fig. 68, B).

In certain cases, when the lode lies at a considerable inclination from the perpendicular, the shaft should be sunk along the lode rather than in a vertical direction.

Adit levels, which facilitate the proper working of a mine, also help to drain it; and, in consequence, they

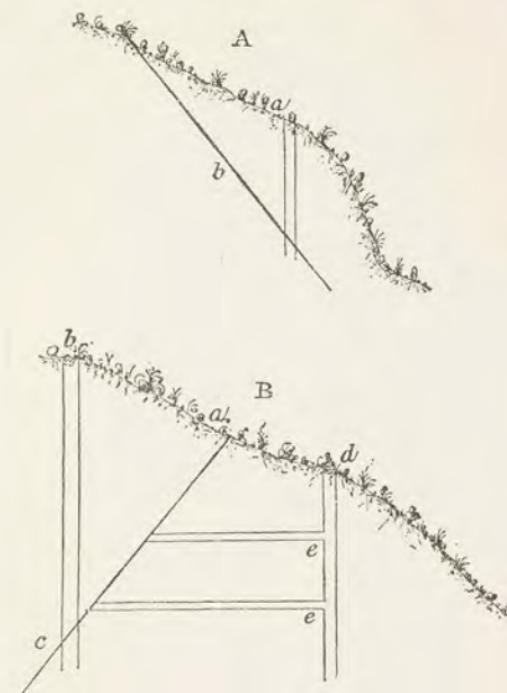


FIG. 68.

A. *b*, Lode. *a*, Shaft.  
 B. *a, c*, Lode. *b d*, Perpendicular shafts. *c*, Where shaft intersects the lode. *e, e*, Crosscuts.

should be driven at as low a level in the valley as possible, and with a very gentle slope, just sufficient to enable the water to flow away.

With regard to the size of shafts and adits, the dimensions of the former vary from 6 by 5 feet to 8 by 6 feet, while the engine shafts are usually 11, 12, or 13 feet by

8 feet; the adits are generally 7 or 6 feet in height, and 4 or 6 feet in width.

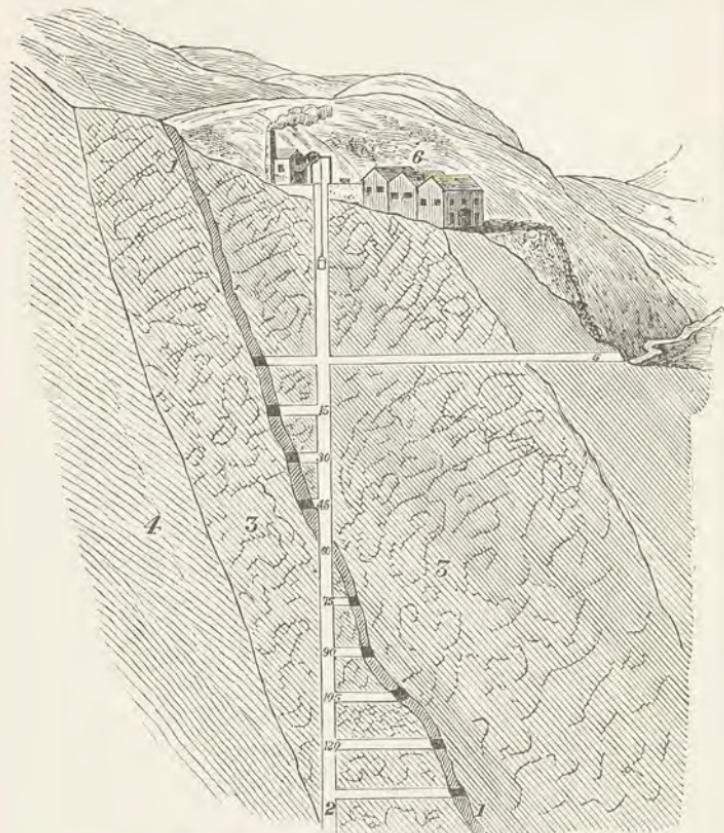


FIG. 69.—LODE WORKED BY VERTICAL SHAFT.

1, Lode. 2, Shaft, 15—120 fathoms crosscuts. 3, Productive strata. 4, Unproductive strata. 5, Adit level. 6, Dressing sheds.

N.B.—The ore is more difficult to raise up a slanting shaft than a perpendicular one.

## APPENDIX.

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Weights and measures of England, France, &c.—Weight of various rocks and metallic ores.—Specific gravity of metals, metallic ores and rocks.—Table of natural sines.—Melting point of various metals.—Table to find the number of ounces of metal to the ton of ore.—Glossary of terms used in connection with prospecting, mining, mineralogy, assaying, &c.—To find weight of ore in a lode, and the value of a mine.

### WEIGHTS AND MEASURES.

#### ENGLISH.

##### *Measures of Length.*

3	barleycorns	= 1 inch.
12	inches	= 1 foot.
3	feet	= 1 yard (36 inches).
5½	yards	= 1 rod, pole, or perch (16½ feet).
4	poles or 100 links	= 1 chain (22 yards or 66 feet.)
10	chains	= 1 furlong (220 yards).
8	furlongs	= 1 mile (1760 yards).

A span = 9 inches ; a fathom = 6 feet ; a league = 3 miles.

##### *Surface Measure.*

144	square inches	= 1 square foot.
9	square feet	= 1 square yard.
30½	square yards	= 1 pole, rod, or perch (square).
16	poles (square)	= 1 chain (sq.) or 484 square yards.
40	poles ,	= 1 rood (sq.) or 1210 square yards.
10	chains ,	= 1 acre (4840 square yards).
640	acres	= 1 square mile.

##### *Solid Measure.*

1728	cubic inches	= 1 cubic foot.
27	cubic feet	= 1 cubic yard.

*Measures of Weight.*

## Troy Measure—

(by which gold, silver, platinum, and precious stones are weighed, though diamonds are by the carat (150 carats = 480 grains).

24 grains	= 1 pennyweight.
20 pennyweights	= 1 ounce (480 grains).
12 ounces	= 1 pound (5760 grains).

## Avoirdupois Weight—

16 drams	= 1 ounce (437½ grains).
16 ounces	= 1 pound (7000 grains).
14 pounds	= 1 stone.
2 stone	= 1 quarter.
4 quarters	= 1 hundredweight (112 lbs.).
20 hundredweight	= 1 ton (2240 lbs.).

A cubic foot of water = nearly 1000 ounces.

Av. oz. = 437½ grains.      1 gallon of water = 10 lbs.  
Troy oz. = 480 grains.

## FRENCH.

*Measures of Length.*

Millimetre ( $\frac{1}{1000}$ of a metre)	=	'03937 inches.
Centimetre ( $\frac{1}{10}$ " )	=	'3937     "
Decimetre ( $\frac{1}{10}$ " )	=	3'937     "
Metre (unit of length)	=	39'3708 ins. or 3'2809 ft.
Decametre (10 metres)	=	32'809 ft. or 10'9363 yds.
Hectometre (100 metres)	=	109'3633 yards.
Kilometre (1000 metres)	=	1093'63 yds. or .6138 miles
Myriametre (10000 metres)	=	6.2138 miles.

*Measures of Surface.*

Centiare ( $\frac{1}{100}$ of an are or sq. metre)	=	1.1960 sq. yds.
Are (unit of surface)	{ =	119.6033 sq. yds. or .0247 acres.
Decare (10 ares)	{ =	1196.033 sq. yds. or .2474 acres.
Hectare (100 ares)	{ =	11960.33 sq. yds. or 2.4736 acres.

*Solid Measure.*

Decistere ( $\frac{1}{10}$ of a stere)	=	3.5317 cubic feet.
Stere (cubic metre)	=	35.3166   ,   ,
Decastere (10 steres)	=	353.1658   ,   ,

*Measures of Weight.*

Milligramme ( $\frac{1}{1000}$ of a gramme)	=	.0154 grains.
Centigramme ( $\frac{1}{100}$ ,   )	=	.1544   ,   ,
Decigramme ( $\frac{1}{10}$ ,   )	=	1.544   ,   ,
Gramme (unit of weight)	=	15.44   ,   ,
Decagramme (10 grammes)	=	154.4   ,   ,
Hectogramme (100 grammes)	=	1544 grs. { 3.2167 oz. Troy or 3.5291 oz Av.
Kilogramme (1000 grammes)	=	32 $\frac{1}{4}$ oz. or 2.2057 lbs.
Myriagramme (10000 grammes)	=	22.057 lbs.

The French metrical system is adopted in most countries, including Spain. The following, however, may be of use in countries where Spanish is spoken :—

*Measures of Length.*

12 puntos	=	1 linea (.077 inch).
12 lineas	=	1 pulgada (.927 inch).
6 pulgadas	=	1 sesma (5.564 inch).
2 sesmas	=	1 pie (.9273 feet).
3 pie	=	1 vara (2.782 feet).
4 varas	=	1 estadal (11.126 feet).
The legua	=	8000 vara.

*Measures of Weight.*

12 granos	=	1 tomin (9.2 grains).
3 tomines	=	1 adarme (27.7 grains).
2 adarmes	=	1 ochava or dracma (55.5 grains).
3 ochavas	=	1 onza (.0634 lbs. or 443.8 grains).
8 onzas	=	1 marco (.5072 lb.).
2 marcos	=	1 libra (1.0144 lb.).

WEIGHT OF VARIOUS ROCKS AND METALLIC  
ORES.

		Lbs. in 1 Cubic Foot.
Antimony—Sulphide	.	281·25
Basalt	.	182
Chalk	.	125
Clay (ordinary)	.	120
Coal—Anthracite	.	58·25
", Bituminous	.	53
Cobalt—Tin White	.	400
Copper—Pyrites	.	259·37
", Grey	.	296·87
", Red	.	375
", Malachite	.	250
Flint	.	162
Fluor Spar	.	196·25
Granite—Grey Aberdeen	.	167
", Red	.	165
Gypsum (natural)	"	140
Iron—Pyrites	.	300
", Magnetic Ore	.	312·5
", Specular	.	281·2
", Brown Hämatite	.	225
Lead—Sulphide (Galena)	.	468·75
", Carbonate	.	493·75
Limestone—Lias	.	156
", Magnesian	.	145
", Compact Mountain	.	170
Manganese—Binoxide	.	300
Marble	.	170
Marl	.	120
Nickel—Glance	.	381·25
Porphyry	.	175—185
Pumicestone	.	57
Quartz	.	166
Sand—River	.	118
", Fine-grained	.	95
Silver (Horn)	.	287·5
Slate	.	160—181
Syenite	.	164

	Lbs. in 1 Cubic Foot
Tin—Oxide . . . . .	406·25
„ Sulphide . . . . .	268·75
Zinc—Blende . . . . .	250
„ Calamine . . . . .	268·75

### THE SPECIFIC GRAVITY OF METALS, METALLIC ORES, AND ROCKS.

#### METALS.

	S.G.
Platinum . . . . .	16·0 — 21·
Gold . . . . .	15·0 — 19·5
Mercury . . . . .	13·5
Lead . . . . .	11·35 — 11·5
Silver . . . . .	10·1 — 11·1
Copper . . . . .	8·5 — 8·9
Iron . . . . .	7·3 — 7·7 <sup>8</sup>

#### COMMON ORES OFTEN MET WITH IN GOLD AND SILVER BEARING VEINS.

	S.G.
Galena . . . . .	7·2 — 7·7
Iron Pyrites . . . . .	4·8 — 5·2
Copper Pyrites . . . . .	4·0 — 4·3
Zinc Blende . . . . .	3·7 — 4·2

#### METALLIC ORES.

	S.G.
Silver—Silver Glance . . . . .	7·2 — 7·4
Ruby Silver (dark) . . . . .	5·7 — 5·9
„ „ (light) . . . . .	5·5 — 5·6
Brittle Silver (Sulphide) . . . . .	5·2 — 6·3
Horn Silver . . . . .	5·5 — 5·6
Mercury—Cinnabar . . . . .	8·0 — 8·99
Tin—Tinstone . . . . .	6·4 — 7·6
Pyrites . . . . .	4·3 — 4·5
Copper—Red or Ruby Copper . . . . .	5·7 — 6·15
Grey . . . . .	5·5 — 5·8
Black Oxide . . . . .	5·2 — 6·3
Horseflesh Ore . . . . .	4·4 — 5·5
Pyrites . . . . .	4·1 — 4·3

	S.G.
Copper—Carbonate (Malachite) .	3·5—4·1
Lead—Sulphide (Galena) .	7·2—7·7
Carbonate (White Lead Ore) .	6·4—6·6
Zinc—Calamine .	4·0—4·5
Blende .	3·7—4·2
Iron—Hæmatite .	4·5—5·3
Magnetic Iron Ore .	4·9—5·9
Brown Iron Ore .	3·6—4·0
Spathic .	3·7—3·9
Pyrites (Mundic) .	4·8—5·2
Antimony—Grey (Sulphide) .	4·5—4·7
Nickel—Kupfernicket .	7·3—1·5
Noumeaita (New Caledonia) .	2·27
Cobalt—Tinwhite .	6·5—7·2
Glance .	6·0
Pyrites .	4·8—5·0
Bloom .	2·91—2·95
Earthy .	3·15—3·29
Manganese—Black Oxide .	4·7—5·0
Wad (Bog Manganese) .	2·0—4·6
Bismuth —Sulphide .	6·4—6·6
Oxide .	4·3

MINERALS FORMING THE GANGUE OR MATRIX IN VEINS.

	S.G.
Quartz .	2·5—2·8
Fluor Spar .	3·0—3·3
Calc Spar .	2·5—2·8
Barytes .	4·3—4·8

ROCKS OF COMMON OCCURRENCE.

	S.G.
Granite }	2·4—2·7
Gneiss }	2·6—2·9
Mica Slate .	2·7—3·0
Syenite .	2·7—3·0
Greenstone Trap .	2·6—3·1
Basalt .	2·3—2·7
Porphyry .	2·6—2·8
Talcose Slate .	2·5—2·8
Clay Slate (Killas) .	2·5—2·8

						S.G.
Chloritic Slate . . . . .						2·7—2·8
Serpentine . . . . .						2·5—2·7
Limestone and Dolomite . . . . .						2·5—2·9
Sandstone . . . . .						1·9—2·7
Shale . . . . .						2·8

## TABLE OF NATURAL SINES.

	0'	10'	20'	30'	40'	50'
0°	.0000	.0029	.0058	.0087	.0116	.0145
1°	.0175	.0204	.0233	.0262	.0291	.0320
2°	.0349	.0378	.0407	.0436	.0465	.0494
3°	.0523	.0552	.0581	.0610	.0640	.0669
4°	.0698	.0727	.0756	.0785	.0814	.0843
5°	.0872	.0901	.0929	.0958	.0987	.1016
6°	.1045	.1074	.1103	.1132	.1161	.1190
7°	.1219	.1248	.1276	.1305	.1334	.1363
8°	.1392	.1421	.1449	.1478	.1507	.1536
9°	.1564	.1593	.1622	.1650	.1679	.1708
10°	.1736	.1765	.1794	.1822	.1851	.1880
11°	.1908	.1937	.1965	.1994	.2022	.2051
12°	.2079	.2108	.2136	.2164	.2193	.2221
13°	.2250	.2278	.2306	.2334	.2363	.2391
14°	.2419	.2447	.2476	.2504	.2532	.2560
15°	.2588	.2616	.2644	.2672	.2700	.2728
16°	.2756	.2784	.2812	.2840	.2868	.2896
17°	.2924	.2952	.2979	.3007	.3035	.3062
18°	.3090	.3118	.3145	.3173	.3201	.3228
19°	.3256	.3283	.3311	.3338	.3365	.3393
20°	.3420	.3448	.3475	.3502	.3529	.3557
21°	.3584	.3611	.3638	.3665	.3692	.3719
22°	.3746	.3773	.3800	.3827	.3854	.3881
23°	.3907	.3934	.3961	.3987	.4014	.4041
24°	.4067	.4094	.4120	.4147	.4173	.4200
25°	.4226	.4253	.4279	.4305	.4331	.4358
26°	.4384	.4410	.4436	.4462	.4488	.4514
27°	.4540	.4566	.4592	.4617	.4643	.4669
28°	.4695	.4720	.4746	.4772	.4797	.4823
29°	.4848	.4874	.4899	.4924	.4950	.4975
30°	.5000	.5025	.5050	.5075	.5100	.5125
31°	.5150	.5175	.5200	.5225	.5250	.5275
32°	.5299	.5324	.5348	.5373	.5398	.5422
33°	.5446	.5471	.5495	.5519	.5544	.5568
34°	.5592	.5616	.5640	.5664	.5688	.5712
35°	.5736	.5760	.5783	.5807	.5831	.5854
36°	.5878	.5901	.5925	.5948	.5972	.5995
37°	.6018	.6041	.6065	.6088	.6111	.6134
38°	.6157	.6180	.6202	.6225	.6248	.6271
39°	.6293	.6316	.6338	.6361	.6383	.6406

	0'	10'	20'	30'	40'	50'
40°	.6428	.6450	.6472	.6494	.6517	.6539
41°	.6561	.6583	.6604	.6626	.6648	.6670
42°	.6691	.6713	.6734	.6756	.6777	.6799
43°	.6820	.6841	.6862	.6884	.6905	.6926
44°	.6947	.6967	.6988	.7009	.7030	.7050
45°	.7071	.7092	.7112	.7133	.7153	.7173
46°	.7193	.7214	.7234	.7254	.7274	.7294
47°	.7314	.7333	.7353	.7373	.7392	.7412
48°	.7431	.7451	.7470	.7490	.7509	.7528
49°	.7547	.7566	.7585	.7604	.7623	.7642
50°	.7660	.7679	.7698	.7716	.7735	.7753
51°	.7771	.7790	.7808	.7826	.7844	.7862
52°	.7880	.7898	.7916	.7934	.7951	.7969
53°	.7986	.8004	.8021	.8039	.8056	.8073
54°	.8090	.8107	.8124	.8141	.8158	.8175
55°	.8192	.8208	.8225	.8241	.8258	.8274
56°	.8290	.8307	.8323	.8339	.8355	.8371
57°	.8387	.8403	.8418	.8434	.8450	.8465
58°	.8480	.8496	.8511	.8526	.8542	.8557
59°	.8572	.8587	.8601	.8616	.8631	.8646
60°	.8660	.8675	.8689	.8704	.8718	.8732
61°	.8746	.8760	.8774	.8788	.8802	.8816
62°	.8829	.8843	.8857	.8870	.8884	.8897
63°	.8910	.8923	.8936	.8949	.8962	.8975
64°	.8988	.9001	.9013	.9026	.9038	.9051
65°	.9063	.9075	.9088	.9100	.9112	.9124
66°	.9135	.9147	.9159	.9171	.9182	.9194
67°	.9205	.9216	.9228	.9239	.9250	.9261
68°	.9272	.9283	.9293	.9304	.9315	.9325
69°	.9336	.9346	.9356	.9367	.9377	.9387
70°	.9397	.9407	.9417	.9426	.9436	.9446
71°	.9455	.9465	.9474	.9483	.9492	.9502
72°	.9511	.9520	.9528	.9537	.9546	.9555
73°	.9563	.9572	.9580	.9588	.9596	.9605
74°	.9613	.9621	.9628	.9636	.9644	.9652
75°	.9659	.9667	.9674	.9681	.9689	.9696
76°	.9703	.9710	.9717	.9724	.9730	.9737
77°	.9744	.9750	.9757	.9763	.9769	.9775
78°	.9781	.9787	.9793	.9799	.9805	.9811
79°	.9816	.9822	.9827	.9833	.9838	.9843
80°	.9848	.9853	.9858	.9863	.9868	.9872
81°	.9877	.9881	.9886	.9890	.9894	.9899
82°	.9903	.9907	.9911	.9914	.9918	.9922
83°	.9925	.9929	.9932	.9936	.9939	.9942
84°	.9945	.9948	.9951	.9954	.9957	.9959
85°	.9962	.9964	.9967	.9969	.9971	.9974
86°	.9976	.9978	.9980	.9981	.9983	.9985
87°	.9986	.9988	.9989	.9990	.9992	.9993
88°	.9994	.9995	.9996	.9997	.9997	.9998
89°	.9998	.9999	.9999	.9999	1'0000	1'0000

## MELTING POINT OF VARIOUS METALS.

Antimony . . . . .	1150°	Fahrenheit.
Copper . . . . .	1990°	"
Gold . . . . .	2000°	"
Iron (Cast) . . . . .	2780°	"
Lead . . . . .	617°	"
Mercury . . . . .	-39°	"
Silver . . . . .	1800°	"
Tin . . . . .	442°	"
Zinc . . . . .	773°	"

TABLE

TO FIND THE NUMBER OF OUNCES TO THE TON  
OF ORE FROM THE WEIGHT OF BUTTON OBTAINED BY CUPELLATION OR OTHER PROCESS.

If 100 grains of ore yield of fine metal :	One ton of ore will yield at same rate :		
grains.	oz.	dwt.	gr.
.001		6	12
.010	3	5	8
.1	32	13	8
1	326	13	8

*Ex.*—Suppose 200 grains of ore yield 2·7 grains of silver, how many ounces is this to the ton of similar ore?

100 grains will evidently yield 1·35 grains; therefore, number of ounces to the ton

$$= 326 \frac{\text{oz.}}{13} \frac{\text{dwt.}}{8} + 3 \times 32 \frac{\text{oz.}}{13} \frac{\text{dwt.}}{8} + 5 \times 3 \frac{\text{oz.}}{5} \frac{\text{dwt.}}{8}$$

which, when worked out, is exactly 441 oz.

Again, suppose 50 grains yielded .02 grains; what is this to the ton?

100 grains will evidently yield .04 grains; therefore the number of ounces to the ton

$$= 4 \times 3 \frac{\text{oz.}}{5} \frac{\text{dwt.}}{8} = 1 \frac{1}{8}$$

**To Find the Weight of Ore in a Lode, and Value of a Property.**

To find approximately the weight of a quantity of ore in a part of a lode (supposing the rectangular planes of surfaces representing the boundaries of the lode are parallel).

(Height  $\times$  width  $\times$  depth) in cubic feet  $\times$  1,000 oz.  $\times$  s.g. of ore, = weight in ounces of ore.

Example:—Find the weight of quartz in part of a lode 6 inches wide, 6 feet long  $\times$  6 feet deep.

$$\begin{aligned} \text{Weight} &= \frac{6 \text{ in.} \times 72 \text{ in.} \times 72 \text{ in.}}{1,728} \times 1,000 \times 2.5, \\ &= 18 \text{ cubic feet} \times 1,000 \times 2.5, \\ &= 45,000 \text{ oz.} = 2,812 \text{ lbs. approximately,} \\ &\quad = \text{a little less than } 1\frac{1}{4} \text{ ton} \\ &\quad (2,240 \text{ lbs.} = 1 \text{ ton}). \end{aligned}$$

N.B.—1,728 cubic inches make one cubic foot, and a cubic foot of water = 1,000 oz.

The reason that 1,000 is a factor in these calculations is that 1,000 ounces is the weight of 1 cubic foot of water, water being taken as the standard unit of specific gravity.

N.B.—In the case of quartz the number of tons in a lode may be known approximately by dividing the cubic feet of the lode by 15 (sometimes by less), as 15 cubic feet of average quartz weighs about 1 ton, though theoretically it might be 14, as in above example.

To find the amount of ore and its value on a property, let A C D B represent the horizontal surface of the property and A B the direction of the outcrop of the lode along the edge of it.

$\angle C A E$  = angle the lode  $B A E F$  makes with the horizon.  
 The angle  $A E C = 90^\circ - \angle C A E$ .

$E$  represents the point of the lode directly under  $C$ , i.e., the point where the perpendicular line to  $A C$  cuts the lode in depth.

The cubical contents in feet of the lode =  $A B \times A E \times$  thickness of lode.

{ Now  $A E = \frac{A C}{\sin(90^\circ - \angle E A C)}$ , and  $A B$  and angle  $\angle E A C$  and the thickness of the lode are also known. }

As in the previous example, the weight in tons can be obtained, supposing the average specific gravity of the ore is known.

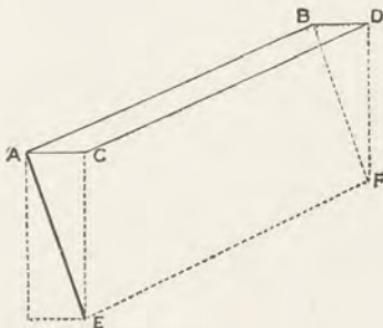


FIG. 70.

To find the value of the property,

weight in tons  $\times$  average yield in ounces per ton of ore,  
 $\times$  value of the metal per ounce,  
 $=$  whole value.

\* Thus, if  $\angle E A C$  is  $60^\circ$ ,  $A E = \frac{A C}{\sin 30^\circ}$ .

The above calculation assumes that the surface is horizontal. Should, for instance, the outcrop be traced on the hill side, then it would be necessary to find also the area of the wedge-like body of ore, bounded by two parallel planes, one plane perpendicular to the base, the basal one, and also that of the slope. The area of such a wedge would be half that of one such as represented in Fig. 70.

## GLOSSARY OF TERMS

USED IN CONNECTION WITH PROSPECTING, MINING,  
MINERALOGY, ASSAYING, ETC.

### A.

ACICULAR—Needle-shaped.

ADAMANTINE—Of diamond lustre.

ADIT—A horizontal entrance to a mine driven from the side of a hill.

AGATE—Name given to certain siliceous minerals.

ALKALIES—Potash, soda (and also ammonia and lithia). Alkalies turn vegetable blue, green; and vegetable yellow, reddish brown. Blues reddened by an acid are restored by an alkali. Alkalies neutralize acids and with them form salts. They precipitate hydrates from their salts.

ALLOY—A mixture of metals by fusion.

ALLUVIAL DEPOSIT—A deposit formed of matter washed down or otherwise transported by a natural agency from higher ground.

ALUMINOUS—Containing alumina.

AMALGAM—A mixture of mercury with another metal, usually gold or silver.

AMALGAMATION—The process of uniting mercury with gold or silver in an ore.

AMORPHOUS—Without any crystallization or definable form.

AMURANG (Ceylon)—Gold ore.

ANALYSIS (in Chemistry)—An examination of the substance to find out the nature of the component parts and their quantities. The former is called qualitative and the latter quantitative analysis.

ANHYDROUS—Without water in its composition.

ANTICLINAL—(*See Chap. II.*)

AQUAFORTIS—Name formerly applied to nitric acid.

AQUA REGIA—A mixture of nitric and muriatic acid. One volume of strong nitric to three or four of hydrochloric acid is a good mixture.

ARBORESCENT—Of a tree-like form.

ARENACEOUS—Sandy.

AREN (Borneo)—Auriferous pay dirt.

ARGENTIFEROUS—Silver-bearing.

ARGILLACEOUS—Clayey.

ARRASTRA—An appliance used for ore-reducing. The ore placed on a hard platform is crushed by means of mules dragging round large stones.

**ARROBA** (Spanish)—25 lbs.

**ARSENIDE**—Compound of a metal with arsenic.

**ASBESTOS**—The usual mineral of this name is fibrous and of a dull greenish colour, with pearly lustre.

**ASSAY**—Process for determining the amount of pure metal in an ore or alloy.

**ATTAL** (Cornwall)—The waste of a mine.

**AURIFEROUS**—Gold-bearing.

**AXE STONE**—A species of jade. It is a silicate of magnesia and alumina.

## B.

**BACK OF A LODE**—That part between the roof of the level and the surface.

**BACK SHIFT**—Afternoon shift of miners.

**BAHAR** (Malay)—Weight of 4 cwt.

**BANK CLAIM**—A mining claim on the bank of a stream.

**BANKET**—A gold-bearing conglomerate in which are white quartz pebbles (S. Africa).

**BAR**—A course of rock, of a different nature to the vein stone, which runs across a lode. A hard ridge of rock crossing a stream is called a bar in Australia, and on the upper side of which gold is likely to be deposited.

**BARROWS**—Heaps of waste stuff raised from the mine.

**BASALT**—(*See Index*).

**BASSET**—Outcrop of a lode or stratum.

**BATEA**—A small, slightly conical dish, generally about 20 inches in diameter and 2½ inches deep, in which gold-bearing soil is washed.

**BATT**—Name given to a highly bituminous shale found in the Coal measures.

**BATTERY**—In mining, a stamping mill.

**BEATAWAY**—A process of working hard ground by means of wedges and sledge hammers.

**BED**—Same as stratum or layer.

**BEDE**—A kind of pickaxe.

**BED ROCK**—The rock underlying an alluvial deposit, and on which at a gold diggings the most payable "dirt" usually rests.

**BELLY**—A swelling mass of ore in a lode.

**BENCH** (Australia)—A terrace on the side of a river. Auriferous benches are termed reef wash.

**BETING** (Malay)—Quartz matrix carrying gold.

**BLACK BAND**—A variety of carbonate of iron.

**BLACK CHALK**—A variety of clay containing carbon.

**BLACK JACK**—Zinc blende.

**BLACK SAND** (Australia)—Name given to black iron and other metals usually accompanying gold.

**BLACK TIN**—Tin ore ready dressed for smelting.

**BLENDE**—Sulphide of zinc.

**BLIND CREEK**—A creek, dry, except during wet weather, or after a freshet caused by melting snow or other cause.

**BLIND LODE**—One that does not show surface croppings.  
**BLOCK CLAIM** (Australia)—A square claim whose boundaries are marked out by posts.  
**BLOCK REEFS** (Australia)—Those with longitudinal contractions.  
**BLOCKING OUT** (Australia)—Washing gold-bearing matter in square blocks.  
**BLOSSOM ROCK**—Coloured vein stone detached from an outcrop.  
**BLUE ELVAN**—Greenstone.  
**BLUE JOHN**—Fluor spar.  
**BLUFF**—A high bank or hill with a precipitous front.  
**BONANZA**—A large and rich body of ore.  
**BONGKAL** (Straits Settlements)—A gold weight = 832·84 grains  
 20 bongkals = 1 catty.  
**BORNASCA**—An unproductive mine.  
**BOTRYOIDAL**—With surface of rounded prominences.  
**BOTTOM**—Bed rock.  
**BOULDERS**—Loose rounded masses of stone detached from the parent rock.  
**BRANCH**—Small string of ore in connection with the main lode.  
**BRECCIA**—A rock in which angular fragments are cemented together.  
**BROWNSPAR**—A kind of dolomite containing, in addition to the carbonates of lime and magnesia, some carbonate of iron.  
**BROWNSTONE** (Australia)—Decomposed iron pyrites.  
**BUCKSTONE**—Rock not producing gold.  
**BUNCH**—A small rich deposit of ore.  
**BURETTE**—A graduated glass tube provided with a stop cock, by means of which a certain quantity of liquid is allowed to drop out.  
**BUTTON**—Name given to the globule of metal which remains in the cupel after fusion. Also applied to the globule of a metal left in the slag from the scorification process.  
**BYON**—Ruby-bearing earth in Burmah.

## C.

**CACO** (Brazil)—A white quartz.  
**CAGE**—Elevator for hoisting and lowering the miners, as well as ore, &c., in the mine.  
**CAIRNGORM**—A variety of quartz, frequently transparent: used as an ornament.  
**CAJON**—(Bolivia) = 50 quintals.  
 (Peru) = 60      "  
 (Chili) = 64      "  
 One marco of gold per cajon of ore = 2 oz. 14 dwt. per ton.  
**CALCINE**—To drive off volatile matter by exposing the substance to a gentle heat, &c.  
**CALCITE**—Carbonate of lime.  
**CAMBRIAN**—Name given to the oldest (except the Laurentian) of the stratified rocks. Found in Wales.  
**CANGA** (Brazil)—A kind of auriferous glacial rock.

CANNY—Lode containing beds of carbonate of lime and fluor spar is called canny.

CAÑON—A deep valley.

CAP ROCK—The formation above the ore.

CARAT—Weight, nearly equal to four grains, used for diamonds and precious stones. With goldsmiths and assayers the term carat is applied to the proportions of gold in an alloy; 24 carats represent fine gold. Thus 18-carat gold signifies that 18 out of 24 parts are pure gold, the rest some other metal.

CARBONATE—Compound formed by union of carbonic acid with a base.

CARBONIFEROUS—Containing coal.

CARBURET—A compound of a metal with carbon.

CARGA (Spain)—A mule's load = 380 lbs.

CASCAHO (Brazil)—A kind of gravel, auriferous and diamondiferous.

CASCAJO (South America)—A decomposed schist on which pay-dirt lies.

CASING—Material between a reef and its walls.

CATEAR (Spain)—To search for minerals.

CAUNTER (Cornwall)—A lode running across a main lode.

CELLULAR—Containing cavities.

CEMENT—A gravel of which the particles are cemented together.

CERRO (Spain)—Rocky hill.

CHERT—A mineral like flint, only of a coarser texture and more brittle. It contains lime as well as silica.

CHLORIDE—Compound of chlorine with an element.

CLAIM—Land staked off by the prospector as his mining property.

CLAVO (Mexico)—A rich "pay" chimney, deep but with horizontal limits.

CLAY-SLATE—Name given to some of the older stratified rocks, which are cleavable across the planes of stratification.

CLEAVAGE—The property of separating into layers.

CLINOMETER—(*See Chap. II.*)

COARSE LODE—One not rich.

COLOR (to show)—An Australian expression when rock or gravel shows traces of gold.

COLORADOS (South America)—Red ores (stained by oxide of iron), similar to "gossan."

COMPACT—Of a firm texture.

CENTRIC—Having the same centre.

CONCHOIDAL—Name given to a certain kind of fracture resembling a bivalve shell.

CONFORMABLE—(*See Chap. II.*)

CONGLOMERATE—Rounded stones cemented together to form a rock.

CONTACT LODE—One between two distinct kinds of rock.

CONTOUR RACE—A watercourse following the contour of the land.

COUNTRY ROCK—The rock on either side of the lode.

CORD (of timber)—A pile of wood 8 feet long, 4 feet high, and 4 feet broad; contains 128 cubic feet.

COSTEAN PITS—Trenches cut at right angles to the strike of the lode.

COURSE OF A LODE—Its direction.  
 CRADLE (Australia)—A wooden apparatus for washing gold dirt.  
 CRATER—The cup-like cavity at the summit of a volcano.  
 CREADERO (South America)—Indication of gold.  
 CREEK—A small stream.  
 CRETACEOUS—Chalky.  
 CREVICING—Collecting gold in the crevices of rock.  
 CROPPINGS—Parts of the vein above the surface.  
 CROSS-COURSES—Veins which usually cross the main lode at right angles.  
 CROSS-CUT—A tunnel or level driven across the lode.  
 CRUCIBLES—Fireproof vessels used in the roasting and melting of ores, &c.  
 CRYSTALLIZED—Having well-defined crystals.  
 CUBICAL—Of the shape of a cube.  
 CUT—To intersect the lode, usually at right angles.

## D.

DAMP—A term applied to dangerous gas escaping from the mineral formation in a mine.  
 DEADS—Ore that will not pay for working. Waste or rubbish in a mine.  
 DÉBRIS—Disintegrated rock deposit.  
 DECANT—To pour off liquid (from the sediment) out of one vessel to another.  
 DECREPITATE—To crackle and fly to pieces when heated.  
 DELTA—The alluvial land at the mouth of a river: usually bounded by two branches of the river, so as to be of a more or less triangular form.  
 DENUDATION—Rock laid bare by water or other agency.  
 DEOXIDATION—The removal of oxygen.  
 DEPOSIT—Matter laid or thrown down; for instance, mud or sand which, after suspension in water, has settled down.  
 DESICCATION—The act of drying.  
 DEVELOPMENT—Work done in opening up a mine.  
 DIAGONAL—From one corner to another opposite.  
 DIALLING—Surveying a mine by means of a dial.  
 DILUVIUM—Drift deposit.  
 DIORITE—Crystalline, whitish, speckled black, or greenish black. Chiefly consisting of felspar and hornblende, with often accessory minerals.  
 DIP—The angle which the lode or bed makes with the horizon is called the dip. (*See Chap. II.*)  
 DISSEMINATED—Scattered throughout a rock in the form of small fragments.  
 DISTILLATION—The driving off vapours from a substance, and allowing them to condense on another surface or vessel.  
 DOLERITE—A kind of basaltic rock.  
 DOLLY (Australia)—An apparatus used in washing gold-bearing rocks,

**DOLOMITE**—A mineral composed of the carbonates of lime and magnesia. Magnesian limestone.

**DRIFT**—A loose alluvial deposit. A level in a mine.

**DRIVINGS**—Horizontal tunnels in a mine.

**DRUSE**—A hollow space in veins lined with crystals.

**DRYBONE**—A term used in America for calamine (carbonate of zinc).

**DUCTILE**—That can be drawn out into wire or threads.

**DUMP**—The place where ore taken from a mine is deposited.

**DUNES**—Small hills formed by sand blown together by the wind.

**DYKE**—Intruded igneous rock which fill up fissures and rents in stratified rocks.

## E.

**EARTHY COAL**—Name sometimes applied to lignite or brown coal.

**EFFLORESCENCE**—An incrustation of powder or threads, due to the loss of the water of crystallization.

**ELBOW**—A sharp bend in a lode.

**ELECTROLYSIS**—Separating chemical compounds into their component parts by means of electricity.

**ELVANS**—Certain granitic and porphyritic rocks that traverse the granite and slate rocks of Cornwall.

**EMERY**—Compact form of corundum. Is hard enough to scratch quartz and several gems.

**EROSION**—The wearing away of.

**EVAPORATE**—To cause to become a vapour.

**EXEMPTED CLAIM** (Australia)—A mine allowed to remain unworked some time.

## F.

**FACE**—The extreme end of tunnel or other mining excavation.

**FALSE BOTTOM**—In alluvial mining the term is applied to a stratum on which pay dirt lies, but underneath which are other bottoms.

**FANEGADO** (Spain)—90½ F. = 100 acres.

**FAST**—Term applied in Cornwall to solid rock immediately beneath the surface drift.

**FATHOM**—6 feet.

**FAULT**—Dislocation along a fissure.

**FEATHER ORE**—A sulphide of lead and antimony.

**FEEDER**—A small vein running into a main lode.

**FERRUGINOUS**—Iron-containing.

**FILTER**—To remove the particles of matter in a liquid by pouring it on to some substance, such as filter paper, so that the liquid runs through and leaves a solid residue behind.

**FISSURE**—A crack or rent in rocks.

**FLATS**—In mining language, decomposed parts of limestone strata which are mineralized. These flats sometimes extend for a long distance horizontally, though they are not very thick.

**FLEXIBLE**—Capable of being bent without elasticity.

**FLINT**—A massive impure variety of silica.

FLOAT-STONE—A cellular quartz rock. The honeycomb quartz detached from a lode is often called float-stone by miners.

FLOAT GOLD—Very fine gold dust which floats on running water.

FLOATING REEF—Lumps of gold-bearing rock found in alluvial beds.

FLOOR—A lode bent into a flat bed.

FLOURED MERCURY—Mercury which is useless for amalgamation purposes, on account of its having a film on it caused by sulphur, arsenic, or some other substance.

FLOUR GOLD—The finest gold dust.

FLUKAN—A vein filled with a soft greasy clay crossing or running in or under a lode.

FLUME—Apparatus (boxing or piping) used for conveying water from higher ground to alluvial gold diggings.

FLUX—A substance used to promote the fusion of metals in the reduction of ore.

FOLIATED—Arranged in leaf-like laminæ (such as mica-schist).

FOOTWALL—The underwall of a lode.

FOOTWAY—Ladders by which miners descend or ascend the shafts of a mine.

Fossil—Term applied to express the animal or vegetable remains found in rocks.

FOSSILIFEROUS—Containing fossils.

FOSSIKING—Same as “Creving.”

FRAME—A sloping board used in the washing of stream tin.

FREEZE (Assaying)—(See Chap. IX., Cupelling).

FRESHET—A flood or overflowing of a river caused by heavy rains or the melting of snow.

FRIABLE—Easily powdered.

FULLER'S EARTH—An unctuous clay (usually of a greenish-grey tint); compact yet friable. Used by fullers to absorb moisture.

FUSE—In blasting, the fire is conveyed to the blasting agency by means of a prepared tape or cord called the fuse.

FUSIBLE—That can be fused or melted.

FUSION—Making liquid by heating.

## G.

GABRO—Name given to a particular kind of rock in which diallage predominates.

GAD—A steel wedge used in underground mining.

GALLERY—A horizontal excavation in a mine.

GAMELLE (Brazil)—Wooden bowl for “panning out” gold.

GANGUE—The non-metallic rock material in a lode.

GEM—A precious stone.

GEYSER—Eruptions of heated water.

GLACIER—A body of ice which descends from the high to the low ground.

GLANCE—Literally, shining. Name applied to certain sulphides.

LOBULE—A small substance of a spherical shape.

**GOSSAN**—Quartz rock with iron oxide as stains or in small cavities. Found on the surface or near the top of a lode.

**GRADE**—An ore which carries a great or comparatively small amount of valuable metal is called respectively a high or low grade ore.

**GRANULATED**—In the form of grains.

**GRANZAS** (Spain)—Poor ores.

**GRASS ROOTS**—At the surface.

**GREDE** (Venezuela)—A yellow iron-stained clay.

**GREENSTONE**—A granular trap rock. Contains hornblende and felspar in small crystals or grains.

**GREISEN**—An altered granitic rock, grey in colour.

**GRIT**—A variety of sandstone of coarse texture.

**GRIZZLY** (America)—Bars set in a flume to intercept the large stones.

**GULCH**—A ravine.

**GULLY**—Feeder of a creek.

**GULLIES** (Cornwall)—Worked-out cavities.

**GUTTER**—Lowest portion of an alluvial gold deposit.

## H.

**HACIENDA** (Spain)—House where ore is melted.

**HADE**—Dip of a lode.

**HALVANS**—Waste of copper ores.

**HALTER** (New Zealand)—A miner working on his own account.

**HANGING WALL**—The upper wall of a lode.

**HARROW** (Australia)—An apparatus used for mixing gold-bearing clays.

**HEADING SIDE**—The under side of a lode.

**HEADINGS**—Coarse gravel above gold-bearing "wash-dirt."

**HEAD-RACE**—An aqueduct for bringing a supply of water.

**HEAVE**—When the lode stops at the end of a level on account of a cross-course, it is said to be "hove."

**HEAVY GOLD** (Australia)—Gold of the size of gunshots.

**HECHADO** (Spain)—The dip of a lode.

**HEMMA** (Sanskrit)—Gold.

**HORN**—A hard siliceous rock.

**HORNSTONE**—(*See Chert.*)

**HORSE**—A term applied to masses of country rock found in a lode.

**HORSE-FLESH ORE**—Purple copper ore.

**HYDRAULIC HOSE** (America)—The hose used to conduct a stream of water, the force of which washes down the face of the alluvial gold bearing deposit.

**HYDROUS**—Containing water in its composition.

## I.

**IGNEOUS**—Certain rocks which have been subjected to heat. (*See Chap. II.*)

**INCH, MINER'S** (America)—Varies in different localities in Western America. The usual one (which discharges 95 cubic feet per hour) is the amount of water that will flow through a horizontal opening, an inch square, under a head of six inches.

**INCLINE**—A slanting shaft.

**INCrustation**—A coating of matter.

**IRIDESCENT**—Showing rainbow colours.

### J.

**JACOTINGA** (Brazil)—Iron ores associated with gold.

**JEWELLER'S SHOP** (Australia)—Rich patch of gold-bearing matter.

**JIGGING**—A process of sorting ores by means of an apparatus having a vertical and rotary motion in water.

**JOINTS**—(*See Chap. II.*)

**JUMPING A CLAIM**—Taking possession of an abandoned or unworked mine by force or otherwise.

### K.

**KAL**—A coarse kind of iron.

**KAOLIN**—(*See Chap. VII.*)

**KILLAS**—A name applied in Cornwall to a hard slate or shale through which lodes run.

### L.

**LAGOON**—A shallow lake, pond, or marsh.

**LAMINA**—A thin slice.

**LAMINATED**—Arranged in laminæ.

**LAVA**—Rock formed by the consolidation of liquid matter which has flowed from a volcano.

**LAVADORES** (Spain)—Gold washings.

**LEAD** (Australia)—Well-defined bed of pay dirt.

**LEADINGS** (Australia)—The unprofitable dirt above pay dirt.

**LEDGE**—Same as a lode.

**LENTICULAR**—Of an onion shape.

**LEVEL**—Horizontal gallery in a mine.

**LIGNEOUS**—Of the nature of wood.

**LITHARGE** (Protoxide of lead)—Used as a flux by assayers.

**LITTLE GIANT**—A movable nozzle attached to hydraulic hose.

**LOADSTONE**—An iron ore consisting of protoxide and peroxide of iron; is magnetic.

**LOAM**—A mixture of fine sand and clay.

**LOB OF GOLD** (Australia)—Rich gold deposit found in an area of small extent.

**LOCATE**—To establish a right to a mining claim.

**LODE**—A longitudinal fissure or chasm filled with ore-bearing matter and between two walls.

**LODE PLOT**—A horizontal lode.

**LONG TOM**—An apparatus used in the washing of gold-bearing “dirt.”

**LUTE**—Pasty matter to close joints of chemical apparatus and to coat surfaces so as to protect them from the action of flame.

## M.

**MACIZO** (Spain)—The part of a lode unworked.

**MALLEABLE**—Capable of being sliced and hammered out.

**MAN ENGINE**—Machine by which men ascend and descend a mine.

**MANTO** (Spain)—A single layer of a stratum.

**MARCO** (Spain)—Weight = 8 ounces.

**MARL**—Clay containing carbonate of lime.

**MATRIX**—The mineral associated with ore in a lode. (*See Chaps. I. and VII.*)

**MEERSCHAUM**—A white soft mineral, dry to the touch, and adhering to the tongue when licked by it. Is a silicate of magnesia. Specific gravity .8 to 1.0 when dry. Occurs in veins or in kidney-shaped nodules in serpentine rocks.

**MESA**—A tableland.

**METALES CALIDOS** (hot metals) (South America)—Minerals capable of amalgamation, such as native silver, hornsilver, &c.

**METALES FRIOS** (cold metals)—Minerals not suitable for the amalgamation process.

**METALLURGY**—Art of extracting metals from their ores, &c.

**METAMORPHIC**—Altered.

**MOCK ORE**—A false kind of mineral.

**MONTON** (Spain)—A pile of ore. In Mexico a monton = 17 quintals.

**MOUNTAIN BLUE**—Blue copper ore.

**MOUNTAIN CORK**—A variety of asbestos.

**MOUNTAIN GREEN**—Malachite.

**MOUNTAIN LIMESTONE**—Carboniferous limestone.

**MUESTRAS** (Spain)—Samples of ores.

**MUFFLE**—A small oven-shaped fire-proof furnace.

**MULLOCK** (Australia)—Débris of the country rock filling a fissure.

**MUNDIC**—Iron pyrites.

**MUSCHELCHALK** (German)—A limestone formation containing fossil shells.

## N.

**NUDULE**—An irregularly-shaped rounded rock.

## O.

**OITAVO** (Spain)—About the eighth part of an ounce.

**OJO** (Spain)—A bunch of ore.

**ONCA** = 442.72 grains troy.

**ORE**—The mineral matter containing metal.  
**ORTHOCLASE**—A certain kind of felspar of various colours.  
**OUTCROP**—The parts of the lode or bed exposed at the surface.  
**OXIDATION**—Conversion of metals into oxides.  
**OXIDE**—The combination of a metal with oxygen.  
**OXIDIZING**—Combining with oxygen.

## P.

**PACOS** (South America)—Mixture of ores of silver with oxides of iron, &c. Usually reddish in colour.  
**PAINT GOLD**—Gold coating quartz pebbles in cement.  
**PALMA** (Spain)—Quarter of a vara or Spanish yard.  
**PAN**—To separate gold from other matter by washing it in a basin, is called "panning out." (*See GOLD, Chap. V.*)  
**PANNIO**—The strata through which a lode passes.  
**PARTING**—Separating the silver from the gold in the button derived by cupellation. The silver is dissolved by nitric acid, the gold remaining as powder.  
**PAY DIRT**—Payable portion of alluvial deposits.  
**PEACH STONE** (Cornwall)—A soft greenish rock found in certain lodes. A peachy lode is often a very good one for tin.  
**PEPIITA** (Spain)—A gold grain.  
**PERMIAN**—(*See Index.*)  
**PEROXIDE**—The oxide which contains greatest amount of oxygen.  
**PETERING**—The pinching out of a vein.  
**PICUL** (China)—A weight of 133½ lbs.  
**PILE** (Australia)—To "make a pile" is to make a lot of money.  
**PIPING**—Washing gold deposits by means of a hose.  
**PITCH** (Cornwall)—The part of a lode let out to be worked on tribute.  
**PLACER**—An auriferous alluvial deposit.  
**PLASTIC**—That can be moulded into different forms.  
**PLATA** (Spain)—Silver.  
**PLATE**—Black shale; a slaty rock.  
**PLATEAU**—Flat table land.  
**PLUMBAGO**—Graphite or black lead.  
**PLUTONIC**—(*See Index.*)  
**POCKET**—A single deposit of mineral, not a vein.  
**POLVILLOS** (Spain)—Good ores.  
     (Mexico)—Tailings.  
**PORPHYRITIC**—Of the nature of porphyry.  
**POST**—Limestone strata divided horizontally with very thin beds of shale.  
**PRAIRIE**—Name given, in some parts of N. America, to an extensive treeless plain.  
**PRECIPITATE**—Name given to solid matter which is separated from a solution by the addition of reagents or by exposure to heat.  
**PREDRAS DE MANO** (Spain)—Good ore specimens.  
**PROSPECTOR**—One who searches for metals or valuable minerals.

**PROSPECTOR'S CLAIM**—A piece of ground, larger than an ordinary claim, given to the discoverer of mineral treasures in a country.

**PUDDING-STONE**—A coarse conglomerate with round pebbles in it.

**PUDDLING** (Australia and America)—Mixing gold-bearing clays with water.

**PULGADA** (Spain)—An inch.

**PULVERIZE**—To powder.

**PYRITES**—Native mineral composed of a metallic sulphide, arsenide, or both.

**PYROXENE**—(*See Augite*).

**PUTTY STONES** (America)—Soft pieces of decomposed rocks found in alluvial diggings.

## Q.

**QUARTZITE**—A granular siliceous sandstone (sometimes of a schistose structure), the grains of quartz being partly crystalline.

**QUARTZOSE**—Rock with a great deal of quartz in it.

**QUINTAL** (Spain)—100 lbs. Spanish, equal to 101½ English lbs.

## R.

**RACE**—An artificial watercourse.

**RACKING**—Separating ores by means of water on an inclined plane.

**RAKE**—A fissure vein.

**RAVINE**—A deep narrow valley.

**REAL** (Spain)—A mining district.

**REAGENT**—A substance added to determine the presence of some other substance by the mutual action of the one towards the other.

**REDUCTION**—The separation of a metal from its compounds.

**REEF** (Australia)—A lode. Outcrop of strata.

**REEF WASH**—Gold-bearing drift where two underground leads join.

**REFRACTORY**—Resisting great heat and difficult to smelt.

**RESIDUE**—The solid matter remaining after a liquid has been filtered or evaporated.

**RIBB**—Lines of ore in the veins.

**RIDER**—A projecting piece of rock crossing a fissure or mineral vein and thus dividing it.

**RIDDLE**—A large iron sieve for sifting ore.

**RIFFLES**—Strips of wood nailed across and rising above the bottom of a sluice, in order to catch the gold during the process of washing.

**RISE**—Same as "stope." The excavation in the back part of a level.

**ROASTING**—Driving off volatile matter, such as sulphur, arsenic, &c., by gently heating the substance and allowing air to have free access to it during the operation by means of stirring.

**Roof**—The top side of a lode or bed.

**ROTTEN REEF**—In S. Africa, a soft deposit found in connection with auriferous conglomerates.

**ROUGH**—The second, or inferior quality, of cassiterite.

**RUN**—Course of a vein. Ore is spoken of as running so much metal per ton.

## S.

**SALAMMONIAC**—Chloride of ammonium.

**SALTING A MINE**—Introducing mineral matter in a mine to deceive purchasers.

**SAMPLE**—Specimens of ore for assaying.

**SCAD (America)**—Uncommon name for a nugget.

**SCALL**—Loose ground.

**SCHISTS**—(*See Index*). Term applied to certain slaty rocks (chiefly metamorphic).

**SCORIFIER**—A shallow fire-proof vessel used in gold and silver assaying.

**SCRIN**—Smallest kind of vein.

**SEAT**—Bottom of a mine.

**SECONDARY ROCKS**—Those older than the Tertiary and newer than the Primary.

**SECTILE**—Easily cut.

**SEDIMENTARY ROCKS**—Deposit of sand, clay, &c., from water.

**SHAFT**—A vertical or inclined excavation in a mine.

**SHAKES**—Caverns in lead mines.

**SHALE**—A schist imperfectly formed.

**SHELF**—The rock on which drifted matter rests.

**SHEPHERDING (Australia)**—Doing just as little work on the mine as is required by mining law.

**SHIFT**—Time during which men work in a mine.

**SHODING**—Tracing pieces of detached veinstones to the parent lode.

**SICKENED MERCURY**—*See "Floured Mercury."*

**SILICA (oxide of silicon)**—Quartz, flint, sand, &c., are nearly pure silica.

**SILICATE**—Combination of a base with a silicic acid.

**SILICEOUS**—Containing silica.

**SILURIAN**—(*See Index*).

**SINK**—An excavation under a level. To “sink” is to excavate downwards in a mine.

**SINTER (Siliceous)**—A silica formation deposited from thermal waters.

**SLAG**—Vitreous mass which covers the fused metal in the smelting hearths. In ironworks it is called cinder.

**SLICKENSIDES**—Name given to smooth striated surfaces of rocks or of mineral lodes.

**SLIDE**—A fracture of strata, or displacement in a mine.

**SLIME ORE**—Finely crushed ore mixed with water to the consistency of mud or slime.

**SLOVAN**—The “cropping out” of a lode or strata.

**SLUICE**—A box or trough through which gold dust is washed. (*See GOLD, Chap. V.*)

**SMALLS**—Small-sized pieces of ore and gangue.

**SPATHIC**—Sparry. Term applied to certain carbonates.

**SPIEGELEISEN**—Variety of highly carbonised pig-iron.

**SPOTTED** (America)—Leads in which the gold is irregularly disseminated.

**STALACTITIC**—Like a stalactite (of the form of a cylinder or cone), as the carbonate of lime incrustations hanging from the roof of limestone caverns. Stalagmites are the columns or cones like these which are on the floor of the caverns.

**STAMP**—A weight used for crushing ore.

**STANNIFEROUS**—Containing tin.

**STEATITE**—A mineral, usually of a greenish colour and soapy to the touch, containing much talc. Soapstone.

**STOPES**—In a mine, the stopes are the steps which the ore assumes while being excavated; when the steps are above the miner's head they are "overhead" stopes; when under his feet "underhand" stopes.

**STRAKE**—An inclined board used in the separation of gold from small quartz.

**STRATUM**—A bed or layer.

**STRIKE**—A find; a valuable development made in an unexpected manner.

**STRIKE**—The straight line in which the plane of a bed or lode cuts the plane of the horizon is called the strike. (*See Chap. II.*)

**STRING**—A thin course of ore.

**STRUCTURE**—The arrangement of the grains or component parts of a mineral.

**STUFF**—Ore associated with the gangue of a lode.

**SUBLIMATE**—The matter formed by condensed vapour when a mineral is heated.

**SUBMETALLIC**—Of imperfect metallic lustre.

**SUBSIDENCE**—The sinking down of.

**SUBTRANSPARENT**—Of imperfect transparency.

**SULPHATE**—A salt containing sulphuric acid.

**SULPHIDE**—A combination of a metal with sulphur.

**SUMPS**—Pits sunk below the foot of mining shafts for the purpose of draining, or proving a lode.

**SWITHER**—A crevice branching from a main lode.

**SUN VEIN**—A vein running in a southerly direction.

**SYNCLINAL**—(*See Chap. II.*)

## T.

**TABLE LAND**—An elevated plain or plateau.

**TAILINGS**—The earthy matter left after it has been washed or otherwise worked for metal.

**TAIL RACE**—An aqueduct for conveying away dirty water and tailings.

**TAN** (China)—Weight = 133½ lbs.

**TARNISHED**—Having the lustre altered by exposure.

**TEARY GROUND**—Ground easily broken up or worked.

**TERTIARY ROCKS**—Those of the most recent formations, and above the Secondary and Primary.

**THERMAL, HOT**—(*e.g.* thermal springs).

**TINSTONE**—Ore containing small grains of oxide of tin; tin ore.

**TIN STUFF**—Ore obtained from a tin lode.

**TON OF FIREWOOD** (Australia)—Average of 50 cubic feet of wood.

**TOURMALINE**—A gem, variously coloured, found sometimes in large transparent crystals in granite, metamorphic rocks, limestone, soapstone, &c.

**TRACHYTE**—A volcanic rock containing felspar, sometimes hornblende and mica. Has a rough surface when broken.

**TRANSLUCENT**—Allowing light to pass through, yet not transparent.

**TRAP**—A volcanic rock. Generally grey or greenish. Diorite, dolerite, greenstone are varieties.

**TRAPPAN ROCKS**—Certain rocks (such as basalt, &c.), which form in terraces.

**TREND**—The course of a vein.

**TRIBUTE**—When miners work on tribute their recompense is a certain percentage of the profits derived from the produce of the mine.

**TUCKER GROUND** (Australia)—Poor ground, just rich enough to allow a miner to buy food and the bare necessities of life.

**TUFA** (Calcareous)—A kind of limestone rock deposited by water containing carbonate of lime. Usually porous.

**TUFA** (Volcanic)—A rock made up of fragments of ash or other volcanic matter, more or less cemented together.

**TYE**—The point where two veins cross. Also, an adit.

## U.

**UNCONFORMABLE**—(*See* Index).

**UNDERLIE**—Dip.

**UNSTRATIFIED**—Not arranged in strata.

## V.

**VANNING**—Washing “tin stuff” by means of a shovel.

**VARA** (Spain)—Length = 33 inches; the Spanish yard.

**VEIN STUFF**—Ore associated with gangue.

**VITREOUS**—Glassy.

**VOLATILE**—Capable of easily passing off as vapour.

**VUGH**—A cavity in a rock or lode.

## W.

WALLS—The boundaries of a lode; the upper one being the “*hanging*,” the lower the “*foot wall*.*”*

WASH DIRT (America and Australia)—Auriferous gravel, sand, clay, &c.

WHIM—An apparatus for drawing the ore of a mine up the shaft.

WINZE—A shaft sunk from level to level.

## Z.

ZEOLITES—Certain hydrous silicates of alumina (with alkali, &c.). They swell up and boil when exposed to the heat of a blowpipe flame.

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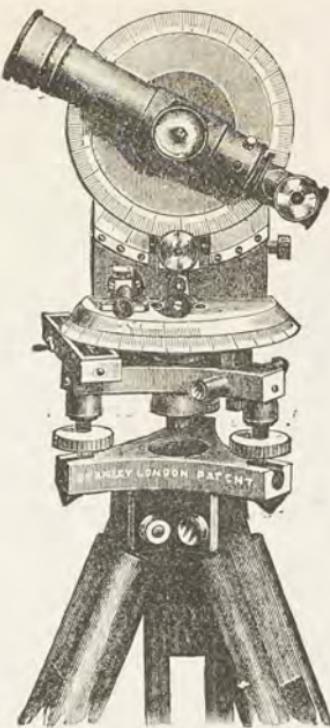
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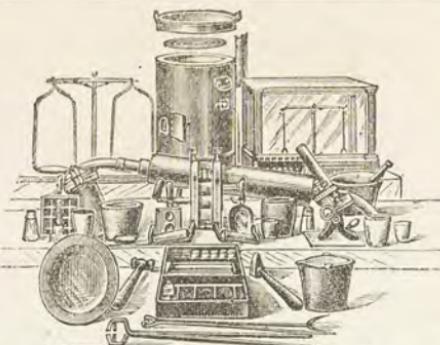
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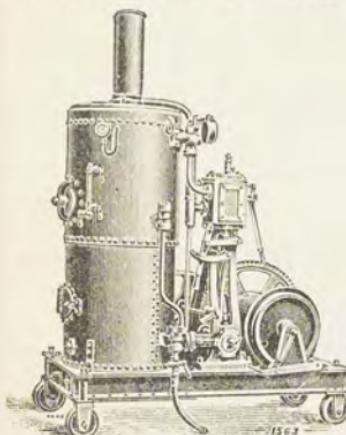
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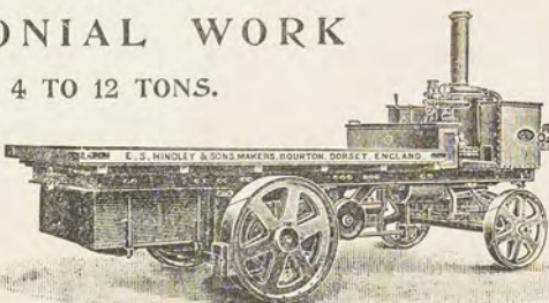
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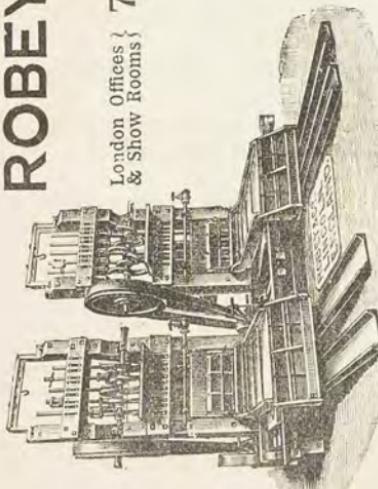
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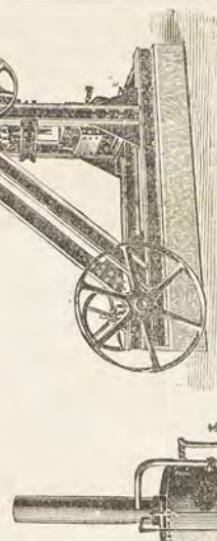
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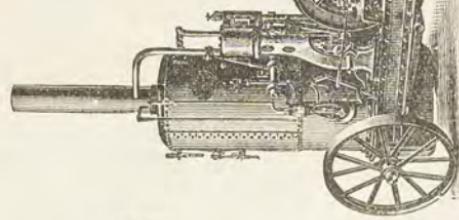
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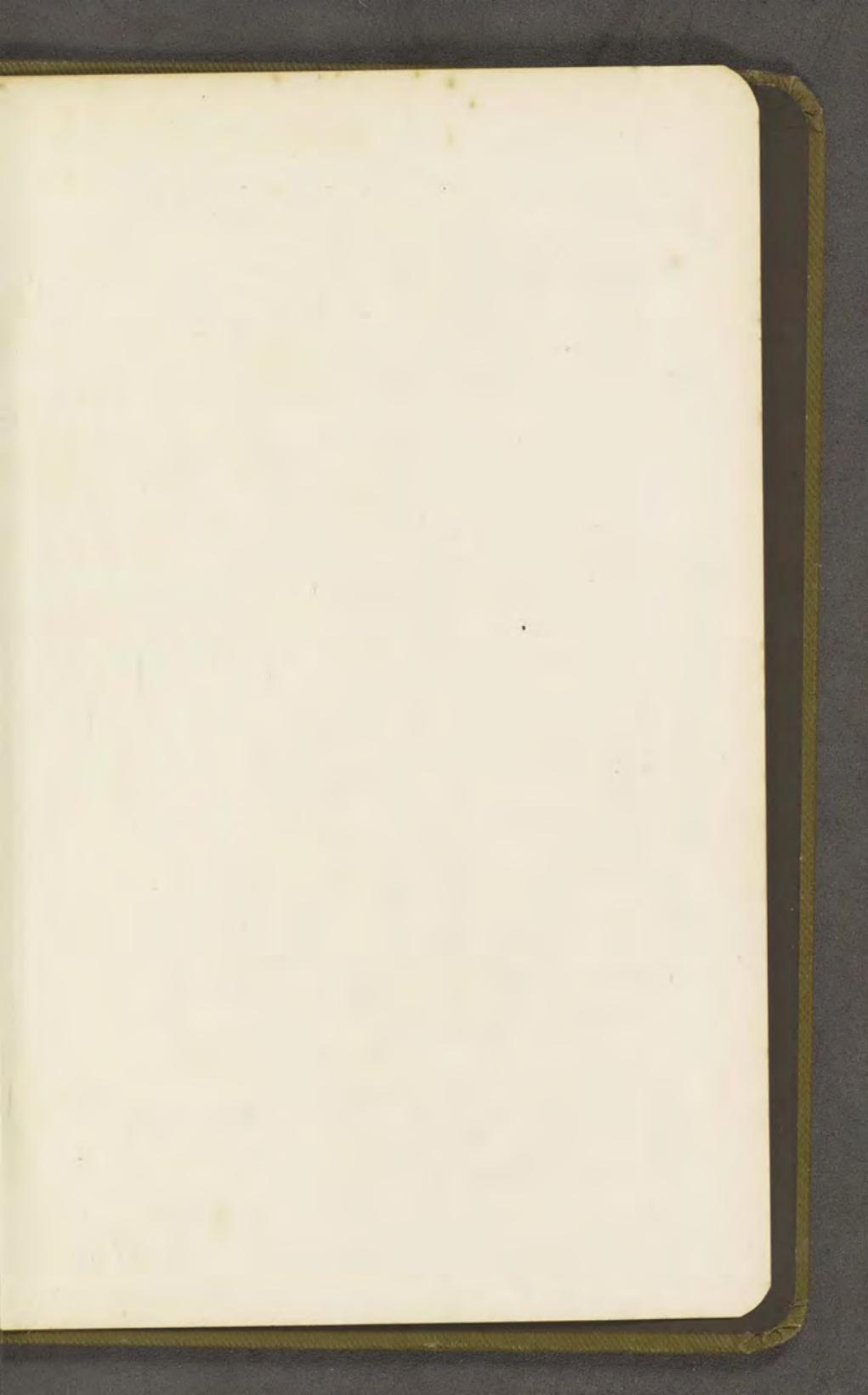
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